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ABSTRACT

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Functional Knowledge in Problem Solving

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For operational problems, this result contrasted with an earlier finding (Greeno & Berger, 1987) that only functional instruction facilitated inference and learning of operational procedures. In this study, component instruction included information about the states of switches and all participants saw a diagram of the device with information about connections between components. Both results are consistent with a characterization of relevant device-model knowledge by Kieras (1984) as including knowledge of device topology: connections between

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Functional Knowledge in Problem Solving

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Abstract

An experiment compared solving of operational and diagnostic problems after different instruction about a fictitious device. Solution of both kinds of problems was facilitated by instruction (1) that focused on functional relations among components of the device or (2) that focused on states of the individual components.

For operational problems, this result contrasted with an earlier finding (Greeno & Berger, 1987) that only functional instruction facilitated inference and learning of operational procedures. In this study, component instruction included information about the states of switches and all participants saw a diagram of the device with information about connections between components. Both results are consistent with a characterization of relevant device-model knowledge by Kieras (1984) as including knowledge of device topology: connections between components and relations of connections to the controlling operations and indicators of the device. Comparison of information in the instructional conditions with planning nets for the operating procedures showed that functional instruction included needed information about connections between components and that component instruction included needed information about states of switches that determine connections between components.

For diagnostic tasks, while solutions of problems was facilitated by both component and functional instruction, some aspects of problem-solving strategy were facilitated only by functional instruction, indicating that the organization of diagnostic problem solving probably depends on integrative features of the problem solver's mental model of the device.

This report presents results of an experiment about the importance of different kinds of knowledge in solving problems involving a physical device.

Research by Kieras and Bovair (1984) showed that knowledge of a mental model of a device is important in learning procedures for operating the device and for solving transfer problems for operating the device requiring construction of novel procedures. Kieras and Bovair concluded that the relevant knowledge in participants' mental models involved the power flow among components of the device. In a subsequent discussion, Kieras (1988) argued that knowledge of how the device works will be valuable in a mental model to the extent that it allows the person to infer the operations of a task procedure. Kieras (1984) concluded, with support of a simulation model, that the important knowledge for inferring procedures are the concept of power flow and knowledge of the system topology, the pattern of connections between internal components and the operating controls and indicators.

In an earlier study (Greeno & Berger, 1987) we obtained results that confirmed and refined Kieras and Bovair's conclusion and Kieras's proposal about useful mental models. In our experiment we differentiated two kinds of knowledge that can be in a mental model of a device applying a distinction introduced by deKleer and Brown (1981). One kind is knowledge about individual components of the device, which deKleer and Brown called knowledge of structure. The other kind is knowledge about functional interactions among the components. In our situation, as in Kieras and Bovair's (1984), the functional interactions involved ways in which power or energy is transformed and transmitted between components of the device. The functional knowledge that we provided turned out to be the dominant factor in facilitating learning and problem solving at the level of operating the device, consistent with Kieras and Bovair's characterization. We also tested participants' abilities to infer procedures based on their mental models, and found that participants who had received functional knowledge were able to infer many of the procedures without instruction. This provided empirical confirmation of Kieras's (1988) proposal that effective mental models allow procedures to be inferred. The instruction that we used led to somewhat higher levels of performance than Kieras and Bovair's, thereby extending their findings to a higher level of proficiency, albeit still in the range of initial learning about the device.

Subsequently, Bibby and Payne (1989) studied problem solving with a derivative of Kieras and Bovair's (1984) device, including diagnostic as well as operational problems. In Bibby and Payne's study different participants learned about the device by studying and reproducing three different descriptions of the device: a diagram that showed connections between device components, a list of procedures, and a table listing conditions in which each indicator light on the device panel would be illuminated. The diagram and table presented the two components of information that Kieras and Bovair identified as components of a device model: connections between device components and relations between device states and operator controls and indicators.

Tasks used by Bibby and Payne (1989) included diagnosing a faulted component of the device and changing an incorrect switch setting. The procedure group found the switch setting task easier than the fault finding task, and the table and diagram groups found the fault finding task easier than the switch setting task. After 240 problems, performance of all groups was similar, but on new kinds of problems that were introduced, the procedure group found a variant of the switch setting tasks easier than a variant of the fault finding tasks, and the table and diagram groups found the fault-finding variant easier than the switch-setting variant. These results confirmed that knowing a model of a device, based in this case on a diagram of the device or a table of conditions associated with indicators, can lead to different performance on tasks, and showed that device-model knowledge can be differentially facilitative of performance in diagnostic problems.

The present study extended our previous experiment (Greeno & Berger, 1987) in two related ways. First, we included tasks that involve diagnosing faults in the device. Our goal in including diagnostic tasks was to begin to differentiate characteristics of mental models that are important in different kinds of tasks. We expected that knowledge about components might play a more significant role in diagnostic problem solving than it does in tasks involving operation of the device because of the need in diagnosis to identify a component that is behaving in an abnormal way.

The second change that we made involved providing more detailed information about the internal structure of components of the device. In the previous experiment, components were "black boxes," and instruction about the individual components specified their input-output behavior and the procedures for controlling their states. In this experiment, the components had subcomponents that were specified in the diagram that was displayed to show the device and described in the instruction. This change added considerably to the amount of information that was presented to participants, and provided a diagram for all participants that showed the device topology, in the form of pictured wires between the components.

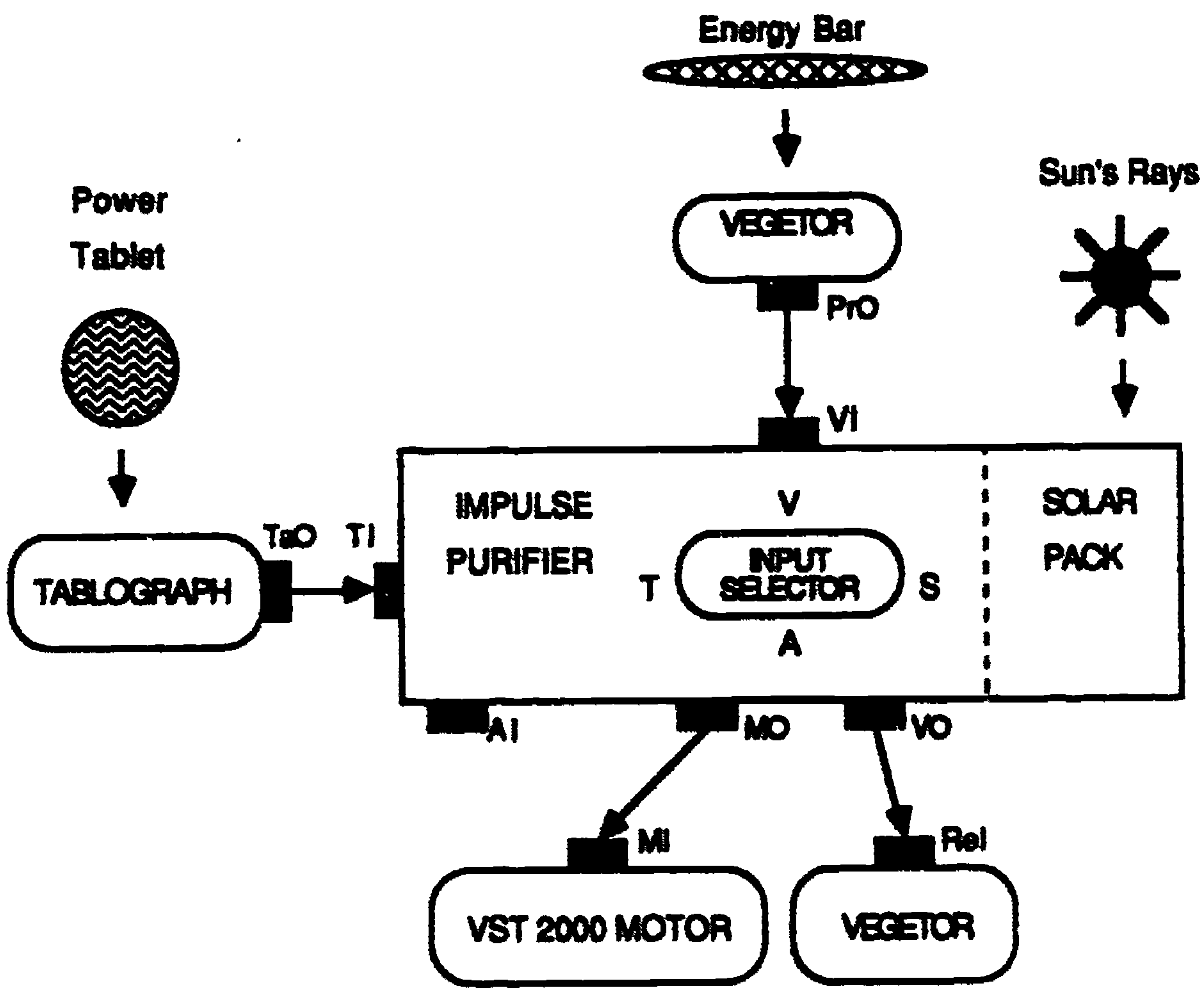


Figure 1. Energy flow diagram for a fictitious device.

As in our previous experiment, we presented different groups of participants with information about a fictitious device that we have designed. The device can be understood easily as an analogue of an ordinary stereo system, although we did not provide that analogy for our participants. The device was described as a science-fiction vehicle that uses energy from three sources: the sun, an energy bar, and a power tablet (analogous to radio waves, a cassette tape, and a phonograph disk). Figure 1 is a diagram, shown to three groups of participants in the experiment, that represents flows of "energy" that can be accomplished with the device. This diagram was also used in the instruction given in our previous experiment to groups who received functional knowledge.

The sun's rays are captured by a solar pack that is included in the component called the impulse purifier. A component called the vegetor contains an energy bar (made of a special vegetable material) whose raw power is captured by a scanner. The tablograph contains the power tablet, and its raw energy is absorbed by a needle. All of these sources have their raw power converted into similar "impulse signals" by local converters. One of these signals is then selected and "laundered" by the impulse purifier after which it is transmitted to the motor. It also can be transmitted to the vegetor to recharge the energy bar.

The representation of the device that participants worked with is shown in Figure 2. This diagram, which enabled simulation of the device's operation in its normal and faulted states, was developed using the Intelligent Maintenance Training System (Towne & Munroe, 1988), a program kindly made available by the Behavioral Technology Laboratory. The components' internal parts, which were not visible in the first experiment, were shown on the screen, and we call these internal parts "constituents." Furthermore, since the topology is visibly evident, two kinds of connections (i.e. wires) are present. One set of connections carries impulse signals (the darker wires in Figure 2), while the other kind of connections (the lighter wires in Figure 2) are for local electricity.

Method

Participants were recruited through posters and advertisements in the University of California's school newspaper and were paid for their participation. The 19 male and 35 female participants ranged in age from 16 to 64 years and were randomly assigned to the six instructional groups.

The fictional device used in the study, called a VST2000, was simulated on a Xerox 1109 work station. Instruction was given at the work station by presentation of text, multiple choice questions and diagrams on the display screen. The procedure tasks were performed by setting switches and knobs, shown on the screen, using the computer's mouse. The diagnostic tasks (which were done on a second day) involved setting the switches for the procedures learned earlier and then locating the malfunctioning part by trying alternate procedures and by "inspecting" individual constituent parts.

A constituent part was inspected by pressing the appropriate mouse button while pointing to the part. The part then appeared in the "Part Inspector" window with its connection ports labeled. The Inspector also included the name of the part, the values of the signals present at the connection ports and a REPLACE button. When pressed, this replaced the Inspected part with a new, non-malfunctioning, part. (See the Part Inspector in the upper right hand corner of Figure 2.)

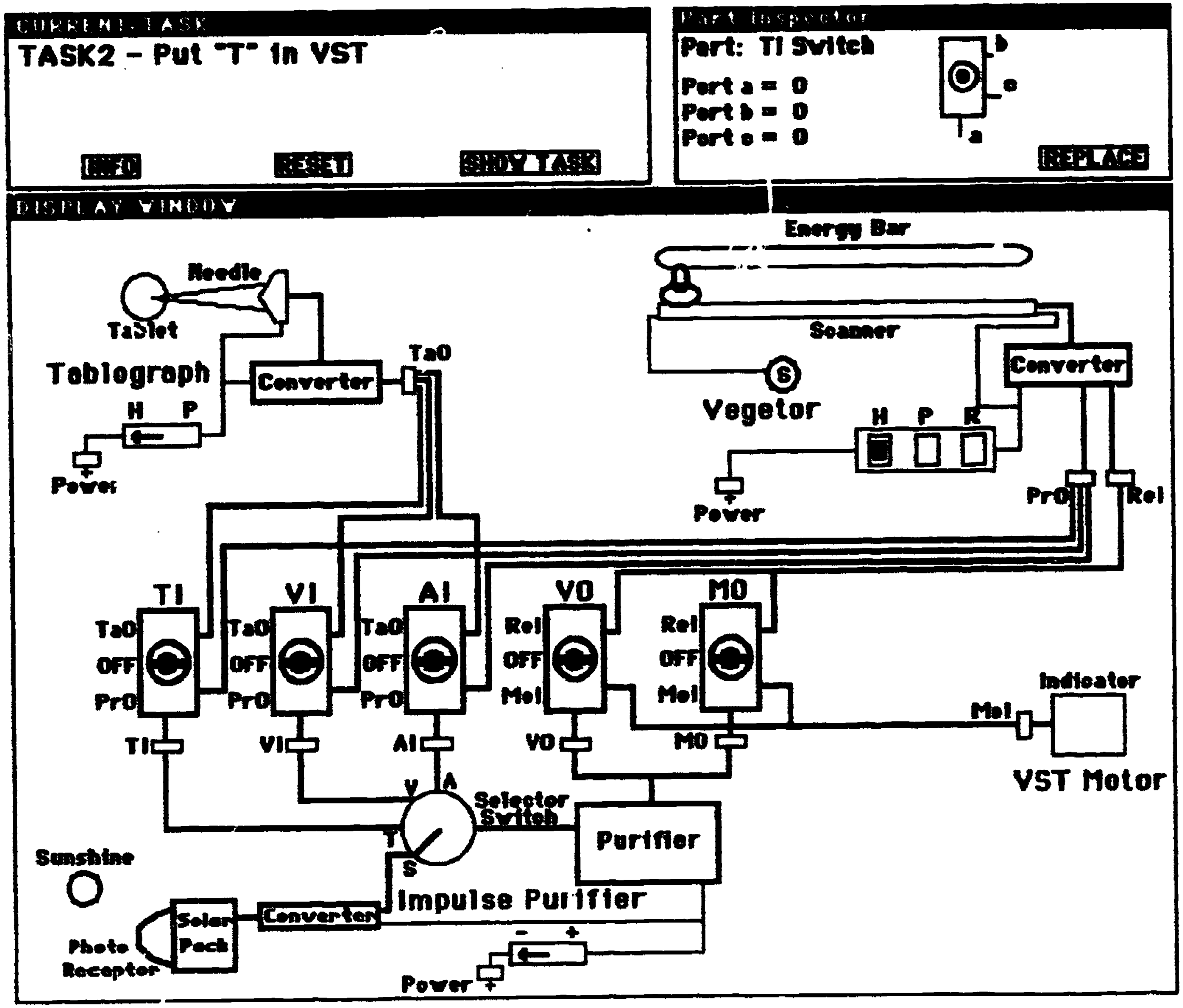


Figure 2. Diagram of the device used in instruction and problem solving.

A printed list of abbreviations was available to the participants at all times. The diagram shown in Figure 1 was available to the participants in the three groups who received functional instruction.

Experimental sequence and tasks.

Day 1: Instruction and Device-Operation Tasks.

Device-Model Instructions. Five groups received instruction in a device model. One group received instruction about functional relations among components. Two other groups received instruction about states of the components of the device. The fourth and fifth groups received instruction about both functional relations and component states. (Two groups received component instruction and two groups received both component and functional instruction because these pairs of groups were given different instruction on Day 2.) Each of these groups' instruction began with an explanation about using the mouse to set switches, and the groups were told that they were going to be asked to operate the device after they completed the instruction. This introductory instruction is shown in Appendix I. Instruction was given using CAI frames, with participants given practice in setting switches relevant to material in their instruction. At the end of the instruction, a test was given, and review was given if any items were missed.

Since changes were made to the device and to the component device model, the device-model instructions were changed from those used in our previous experiment (Greeno & Berger, 1987). While the new image did not change the functional description of the device, the component device model information increased greatly to include all of the constituent parts. In particular, the switches of the device were considered as components, and the component instruction discussed their behavior in passing energy between specified ports. (In the previous experiment, switches were not discussed in the component instruction, being treated only as means of connecting the components shown in Figure 1.) The component group's instruction now also alluded to the topology evident on the screen.

The functional instruction consisted of 32 frames, presented in Appendix II. This instruction explained the functional relations among components and switch settings that determined connections between components: the input switches (TI, VI and AI) and the selector switch on the purifier. The energy-flow diagram (Figure 1) was available to the participants who had functional instruction. The sequence of instruction was top-down in nature beginning with a characterization of the device and four functions that its components perform: capturing, transforming, transmitting, and purifying energy. The three sources of energy were then described, then the function of passing energy from any of the sources to the purifier and then on to the destination devices (i.e. the motor or the vegetor for recharging).

Component instruction consisted of 59 CAI screens of instruction, shown in Appendix III. This instruction presented the five components and all of their constituent parts. For each constituent part a diagram was shown with its ports labeled, and the instruction described the states of the part based upon signals arriving at the ports or, in the case of a switch, according to its possible settings. After describing all of a component's constituents, the states of the whole component were described.

The component instruction also included many references to the two types of signals (i.e. local electricity and impulse signals) present in the system. Each port was described as either an input or output port for one of the signal types. The values of local electricity were stated as either 0 or 1 (although there was one instance of a value 2), while the values of an impulse signal could be 0, 1, 2 or 3 (i.e. no signal, Tablograph power, Vegetor power or Solar power, respectively).

The combined functional and component presentation consisted of 90 frames of instruction, shown in Appendix IV, that combined the information in the functional and component instructional sequences. The instruction followed the top-down organization of the functional instruction, with the component and constituent part descriptions incorporated when the various components were discussed.

Initial problem solving. After being told about a "help" window and a review about using the mouse, participants in the five instructed groups were asked to try to perform four tasks without further instruction. Data about the tasks are shown in Table 1. The switches referred to as "connections" involved connections between components and were discussed in the functional device-model instruction. The switches referred to as "states" involved states of individual components, and the local effects of both the connection and state switches were discussed in the component device-model instruction. However, none of the instruction discussed switch settings in relation to tasks of the kind used in the test or in learning.

The Solar task involved setting switches so the device would run with solar energy. This consisted of setting IP to + (turning purifier power on), changing MO to MoI (connecting motor output to motor input), and turning the Sunshine on (the selector switch's initial setting is S, that is, selecting solar input to the purifier). The Tab task involved setting switches so the device would run with energy from the power tablet in the tablograph. The Veg task was to change switches so the device would run with energy from the energy bar in the vegetor. The Solar+Veg task was to set switches so the device would run with solar energy and, at the same time, recharge the energy bar in the vegetor.

Table 1

Characteristics of Experimental Tasks

Task	Switches	State Switches	Connection Switches
Solar	3	2	1
Tab	5	2	3
Veg	5	2	3
Solar+Veg	7	5	4

Five minutes were given for each task, although the limit was not enforced strictly if the participant was close to a solution when time elapsed. Participants were not given feedback by the experimenter, but they could tell whether they had succeeded by observing the VST indicator. For example, the VST indicator showed the letter "S" if the system was correctly set to run with solar energy, or the letter "T" if the switches were set to run with energy from the power tablet.

Learning trials. After the initial test of problem solving, participants in the instructed groups proceeded to learning trials, a transfer trial, and a recall trial. Participants in the uninstructed group were shown how to use the mouse and the "help" window (Appendix I), and began with the learning trials.

In the first learning trial, instructions for performing the four tasks were presented, and the participant set switches for each task according to the instructions. The instructions are presented in Appendix V. After all four tasks were completed with the instructions, the participant was asked to perform each task without the instructions. No feedback was given during this test. If a task was performed without an error, it was removed from that participant's set of tasks. If the participant made a minor error on a task or required more than one attempt to set the switches correctly, the task was given a second time (after all the tasks had been given once), and the task was removed if it was performed accurately. A second learning trial was given for tasks that were not removed in the first trial. This involved presenting the instructions for the tasks and having the participant set switches for them, as in the first trial. After the second learning trial, the participant was tested a second time on those tasks.

Transfer problem. After the learning trials, a transfer task was presented. In the transfer task, the participant was asked to set switches so the device would run with energy from the power tablet, but without setting the TI switch to TaO. (This simulated a condition where the TI input plug is broken.) One correct solution is to set the AI switch to TaO (connect the auxiliary input to the tablograph output) and set the selector switch to A. The transfer task has the same number of functional and component switch settings as the Tab task.

Finally, participants were asked to perform the Veg task and the Solar+Veg task in a recall test.

Day 2: Device Malfunction Diagnostics.

The second day began with the five instructed groups rereading the device model instruction they read on Day 1. One of the Component groups and one of the Both groups had their instruction augmented with the addition of specific malfunction instruction. This instruction is presented in Appendix VI. Furthermore, on this day the groups were told that after reading the instruction they were going to be asked to fix the device when it malfunctioned. There was no review quiz given on Day 2.

Both the instructed and uninstructed groups were then told the "ground rules" for the diagnostic tasks, with instruction that is presented in Appendix VII. The groups were informed that there were two available aids in figuring out the malfunctioning part, the Part Inspector and the operating instructions for the correct procedure. The participants were advised that only one part breaks at a time, and that trying alternate switch settings or procedures may be helpful in locating the broken part. Finally, all participants were told that replacing a part is expensive, so they should have (and state) their reasons for replacing the part. No specific debugging training was presented to the groups before they moved onto the tasks.

There were a total of nine malfunction tasks, and each participant attempted at least the first six tasks. The tasks were of varying levels of difficulty, and the problems were classified as one of three types: Functional, Switch, or Wire. A Functional malfunction involved a part that was presented in the functional device model instruction; a Switch malfunction concerned a part that had failed in its switching mechanism; and a Wire malfunction meant that a wire had broken and was not passing its signal. Appendix VIII includes a description of each malfunction and an optimal solution for each.

For each diagnostic task the participants were first asked to perform one of the operating procedures from Day 1. After setting the appropriate switches, the participants could tell that the device was broken because the indicator did not show the corresponding letter. They then tried to locate the broken constituent with alternate procedures or with the Part Inspector. Participants knew that they had replaced correct part when the appropriate letter appeared in the indicator.

Participants were given an unlimited amount of time to complete each task. The experimenter did not aid the participant but did ask questions to determine the participant's current state in resolving the problem and to elicit the reasons for his or her actions.

Results

Day 1: Operating Procedures

Mean times spent in the three kinds of instruction on Day 1 were as follows: Component = 40 minutes[1], Functional = 27 minutes, and Both = 40 minutes.

Table 2 shows performance on the initial problem-solving trial after the instruction. Performance on a task was scored as correct if a participant had all of the switches set correctly when the trial ended. Correctness of a switch was scored according to the participant's final settings.

Table 2

Proportion Correct on Initial Problem-Solving Trial

Instruction	Complete Tasks	State Switches	Connection Switches
Component	.42	.68	.57
Functional	.42	.69	.85
Cmpt&Fctnl	.75	.86	.92

In our previous experiment (Greeno & Berger, 1987), the functional instruction was much more effective than the component instruction. In these data, both kinds of instruction were effective.

In the previous experiment, the group that received both component and functional instruction was not significantly better than the group that received functional instruction, and the average of those two groups was better than the component group. Here, the group with both component and functional instruction was significantly better than the group with functional instruction in the proportion of correct complete tasks; with 95% confidence, $\mu_{C\&F} - \mu_F = 0.33 \pm 0.29$. The average of the two groups with functional instruction was not significantly better than the group with only component instruction in correct complete tasks, $(\mu_{C\&F} + \mu_F)/2 - \mu_C = 0.17 \pm 0.22$.

In the total number of correct switches the result was like that of the previous experiment. The group with both component and functional instruction was not significantly better than the group with only functional instruction, $\mu_{C\&F} - \mu_F = 0.13 \pm$

[1]Data on instruction times for one of the 18 participants in the Component conditions were not available; the time reported was the mean for the remaining 17 participants.

0.22; and the average of the two groups with functional instruction was significantly better than the group with only component instruction, $(\mu_{C\&F} + \mu_F)/2 - \mu_C = 0.19 \pm 0.17$.

In the previous experiment, the group with component instruction had difficulty inferring the connection switches in the first problem, but the group with functional instruction inferred the state switches as successfully as the group with both functional and component instruction. That was not the case in this experiment. The difference between state and connection switches was greater in the group with functional instruction than it was in the group with both functional and component instruction, $\mu_{C\&F} - \mu_F = 0.112 \pm 0.110$, indicating that the component instruction added significantly to the ability to infer the state switches. The comparison of the difference between state and connection switches between the two groups with functional instruction and the group with only component instruction also was significant, showing that the apparent interaction between instruction and switch type was reliable, $(\mu_{C\&F} + \mu_F)/2 - \mu_C = 0.15 \pm 0.08$.

Table 3 shows data from the learning trials that followed the initial test. The proportions of errors were summed across trials because tasks were eliminated when the participant performed them correctly.

Table 3

Sums of Proportions of Errors on Tests Following Learning Trials

Instruction	Complete Tasks	State Switches	Connection Switches
None	0.28	0.05	0.08
Component	0.18	0.04	0.07
Functional	0.06	0.01	0.04
Cmpt&Fctnl	0.02	0.00	0.02

These results match those of the previous experiment very closely. The major difference is in better performance by the participants who had no device-model instruction at all.

As in the previous experiment, the functional instruction seemed to provide a more effective basis for learning than the component instruction. Neither group with functional instruction made errors with any substantial frequency. In the number of errors on complete tasks, the group with both functional and component instruction did not differ significantly from the group with only functional instruction, $\mu_{C\&F} - \mu_F = 0.03 \pm 0.16$. The groups with functional instruction made fewer errors than the group with only component instruction, $(\mu_{C\&F} + \mu_F)/2 - \mu_C = -0.14 \pm 0.13$. And the three groups with device-model instruction made fewer errors than the group with no instruction, $(\mu_{C\&F} + \mu_F + \mu_C)/3 - \mu_N = -0.19 \pm 0.15$. The proportions of errors on individual switches were all small, and differences among them were not significant.

Table 4 shows the proportions of correct solutions and switch settings for the transfer problem.

Table 4

Proportions Correct on the Transfer Task

Instruction	Complete Task	State Switches	Connection Switches
None	.89	1.00	.96
Component	.88	1.00	.93
Functional	1.00	1.00	1.00
Cmpt&Fctnl	.99	1.00	.98

Compared with the previous experiment, these results differ primarily in much better performance by the groups with no instruction and only component instruction. The small differences among conditions favored the groups with functional instruction, but none of the differences were significant.

Table 5 shows the data for performance on the recall tasks. Performance was nearly perfect in all the conditions.

Table 5

Proportions Correct in Recall

Instruction	Complete Tasks	State Switches	Connection Switches
None	.94	1.00	.97
Component	.94	.98	.99
Functional	1.00	1.00	1.00
Cmpt&Fctnl	1.00	1.00	1.00

Day 2: Diagnostic Tasks

Times used in instruction on Day 2 were as follows: Component, Not Augmented = 21 minutes[2]; Component, Augmented = 29 minutes on the review and 6 minutes on malfunction information; Functional, 10 minutes; Both, Not Augmented = 26 minutes; Both, Augmented = 30 minutes on the review and 4 minutes on malfunction information.

Table 6 shows proportions of correct solutions on the six diagnostic problems, and proportions of problems that were solved correctly with correct explanations given of the nature of the malfunction. The participants who had component instruction were in two different conditions, one that received augmented instruction about malfunctions of components and the other that did not. These conditions are presented separately in Table 6, and data are also presented for the Component groups together and for the Component & Functional groups together. The difference between groups with and without augmented instruction was not significant on any measure that we examined, so all analyses are reported for the combined Component and Component & Functional groups.

[2]Data on instruction times for one of the nine participants in the Component, Not Augmented condition were not available. The mean reported was for the remaining eight participants.

Table 6

Proportions Correct in Diagnostic Tasks

Instruction	Tasks		Tasks and Explanations	
None		.70		.52
Cmpt, Not Augmented	.87		.85	
Cmpt, Augmented	.93		.83	
Component		.90		.84
Functional		.93		.78
Cmpt&Fctnl, Not Augmented	.98		.94	
Cmpt&Fctl, Augmented	.96		.89	
Component & Functional		.97		.92

On correct tasks, both the effect of functional instruction and the effect of component instruction were significant, $(\mu_{C\&F} + \mu_F)/2 - (\mu_C + \mu_N)/2 = 0.15 \pm 0.08$, and $(\mu_{C\&F} + \mu_C)/2 - (\mu_F + \mu_N)/2 = 0.12 \pm 0.08$. The interaction was not significant, $(\mu_{C\&F} - \mu_F) - (\mu_C - \mu_N) = 0.15 \pm 0.16$.

On correct tasks and explanations, the effects of functional instruction and component instruction and the interaction were all significant, $(\mu_{C\&F} + \mu_F)/2 - (\mu_C + \mu_N)/2 = 0.17 \pm 0.09$, $(\mu_{C\&F} + \mu_C)/2 - (\mu_F + \mu_N)/2 = 0.23 \pm 0.09$, and $(\mu_{C\&F} - \mu_F) - (\mu_C - \mu_N) = -0.18 \pm 0.17$.

Table 7 shows results for a measure of understanding in solutions of the diagnostic problems. Participants were discouraged from replacing components arbitrarily, and were required to state a hypothesis when they wanted to replace a component. It was possible in each problem to determine which component was at fault without replacing any components. Table 7 shows frequencies of occurrence of replacing components that were not faulted.

Table 7

Replacements of Unflawed Components

Instruction	Proportions of Tasks		Mean Number Per Task	
None		.37		.48
Cmpt, Not Augmented	.11		.22	
Cmpt, Augmented	.20		.41	
Component		.16		.32
Functional		.17		.18
Cmpt&Fctnl, Not Augmented	.13		.20	
Cmpt&Fctl, Augmented	.11		.17	
Component & Functional		.12		.18

The effects of both functional and component instruction were significant in the proportions of problems where unflawed components were replaced, $(\mu_{C\&F} + \mu_F)/2 - (\mu_C + \mu_N)/2 = -0.12 \pm 0.09$, and $(\mu_{C\&F} + \mu_C)/2 - (\mu_F + \mu_N)/2 = -0.13 \pm 0.09$. The interaction was not significant, $(\mu_{C\&F} - \mu_F) - (\mu_C - \mu_N) = 0.170 \pm 0.174$. Regarding the mean number of replacements of unflawed components per problem, the effect of functional instruction was significant, $(\mu_{C\&F} + \mu_F)/2 - (\mu_C + \mu_N)/2 = -0.21 \pm 0.16$. The effect of component instruction and the interaction were not significant, $(\mu_{C\&F} + \mu_C)/2 - (\mu_F + \mu_N)/2 = -0.08 \pm 0.16$ and $(\mu_{C\&F} - \mu_F) - (\mu_C - \mu_N) = 0.16 \pm 0.32$.

We examined participants' use of inspections as a diagnostic operation. Table 8 shows the results. First, when a participant inspected one or more components, the protocol was used to make a judgment whether the participant was inspecting the component for a reason, or whether the inspection was "haphazard." The first column in Table 8 shows the mean number of "haphazard" inspections per problem. The second column shows a statistic obtained by examining the second inspection that a participant made on a problem in relation to the first inspection on that problem. The result of inspecting a component generally allows other components to be eliminated as possibly being flawed. The second column of Table 8 shows the mean proportion of second inspections that were redundant with the results of the participant's first inspection.

There was a trend in the judged "haphazard" inspections in the direction of an advantage for participants with device-model instruction, but the effects were not significant. In the proportions of redundant inspections, the effect of functional instruction was significant, $(\mu_{C\&F} + \mu_F)/2 - (\mu_C + \mu_N)/2 = -0.07 \pm 0.06$. The effect of component instruction and the interaction on this measure were very near zero, $(\mu_{C\&F} + \mu_C)/2 - (\mu_F + \mu_N)/2 = -0.01 \pm 0.06$ and $(\mu_{C\&F} - \mu_F) - (\mu_C - \mu_N) = 0.01 \pm 0.13$.

Table 8

Haphazard and Redundant Inspections

Instruction	Mean "Haphazard" Inspections		Mean Proportion Redundant Inspections	
None		0.18		.11
Cmpt, Not Augmented	0.06		.11	
Cmpt, Augmented	0.09		.09	
Component		0.07		.10
Functional		0.06		.04
Cmpt&Fctnl, Not Augmented	0.09		.04	
Cmpt&Fctl, Augmented	0.04		.02	
Component & Functional		0.06		.03

Finally, Table 9 involves use of a diagnostic method. Information can often be obtained efficiently by seeing whether the device operates properly in a setting different from the one that is known to be malfunctioning.

In the mean proportion of tasks on which participants used an alternate operation, the effect of functional instruction was significant, $(\mu_{C\&F} + \mu_F)/2 - (\mu_C + \mu_N)/2 = 0.35 \pm 0.14$. The effect of component instruction and the interaction were not significant, $(\mu_{C\&F} + \mu_C)/2 - (\mu_F + \mu_N)/2 = 0.04 \pm 0.14$ and $(\mu_{C\&F} - \mu_F) - (\mu_C - \mu_N) = -0.12 \pm 0.29$. In the mean number of alternate operations used per task, the effect of functional instruction was significant, $(\mu_{C\&F} + \mu_F)/2 - (\mu_C + \mu_N)/2 = 0.73 \pm 0.37$. The effect of component instruction and the interaction were not significant, $(\mu_{C\&F} + \mu_C)/2 - (\mu_F + \mu_N)/2 = -0.05 \pm 0.37$ and $(\mu_{C\&F} - \mu_F) - (\mu_C - \mu_N) = 0.13 \pm 0.74$.

Conclusions

The results of this experiment further demonstrate the importance of knowledge about functional interactions among components in an individual's mental model of a device. Our findings support Kieras's (1984) conclusion that knowledge of the system topology and connections between internal components and the operating controls are important components of a mental model. As in the previous experiment, instruction that presented information about functional relations between components facilitated problem solving and learning.

There also were differences between these results and our previous findings. The component instruction of this experiment facilitated problem solving and learning, while the component instruction of the previous experiment did not. It is likely that this occurred because in this experiment the component instruction included discussion of the switches as components, which provided instruction about relations between the controlling operations and the device topology.

Table 9

Alternate Operations

Instruction	Mean Proportion of Problems	Mean Number Per Problem
None	.39	0.74
Cmpt, Not Augmented	.46	0.63
Cmpt, Augmented	.52	0.63
Component	.49	0.63
Functional	.80	1.41
Cmpt&Fctnl, Not Augmented	.78	1.39
Cmpt&Fctl, Augmented	.78	1.46
Component & Functional	.78	1.42

Second, participants without device-model instruction in this experiment were more successful in learning than the corresponding participants in the previous experiment. It seems likely that this resulted from the information provided in the diagram of the device that all participants had in this experiment. The device diagram represented the device topology, allowing participants to infer functional relations if they were not instructed.

In the diagnostic problems, participants who had received functional instruction performed more successfully than participants without functional instruction in several ways: they solved more problems correctly, replaced fewer unflawed components, performed fewer redundant inspections, and used more alternate operations. Participants with instruction about components also were more successful in the number of problems they solved and in replacing unflawed components in fewer problems, but did not show the more strategic features of diagnostic problem solving reflected in the avoidance of redundant inspections or use of alternate operations.

Discussion

We characterize knowledge for solving problems of operating and diagnosing the VST2000 in terms of three schemata and specific items of information that are used in generating solutions of problems. Figure 3 shows one of the schemata, a schema for getting power from one component a to another component b.

Consequence: *power-from* (b,a)   {a and b are components}

Requires: *power* (a) = +

AND

$\exists x \exists y [\mathit{port}(x,a) \wedge \mathit{port}(y,b) \wedge \mathit{connect}(x,y)]$

OR

$\exists t [\mathit{component}(t) \wedge \exists x \exists y [\mathit{port}(x,a) \wedge \mathit{port}(y,b) \wedge \mathit{connect}(x,y)] \wedge \mathit{power\text{-}from}(b,t)]$

Figure 3. Schema to get power from a to b.

The schema has two requirements: (1) that component a has power, and (2) either that a port of a and a port of b are connected, or that there is some intermediate component t with a port that is connected to a port of a, and that b has power from t.

The second schema, for having power at a component, is in Figure 4.

Consequence: *power* (c) = +   {c is a component}

Requires: power in source of c;

c on

Figure 4. Schema for having power at a component.

The sources of the solar pack, tablograph, and vegetor are, respectively, the sunshine (which must be on), the power tablet (which always has power), and the vegetable bar (which must be charged). The source of the purifier is considered to be the port at the selector switch that is connected with the purifier by a wire.

The third schema, for connecting two ports, is shown in Figure 5.

Consequence: *connect* (x,y)   {x and y are ports}

Requires: $\exists$ w [*wire* (w) $\wedge$ *attach* (w,x) $\wedge$ *attach* (w,y)]

OR

$\exists$ s $\exists$ u $\exists$ v [*switch* (s) $\wedge$ *single-port* (u,s) $\wedge$ *connect* (x,u) $\wedge$ *alternate-port* (v,s) $\wedge$ *connect* (y,v) $\wedge$ *switch-set* (s,v)]

OR

connect (y,x)

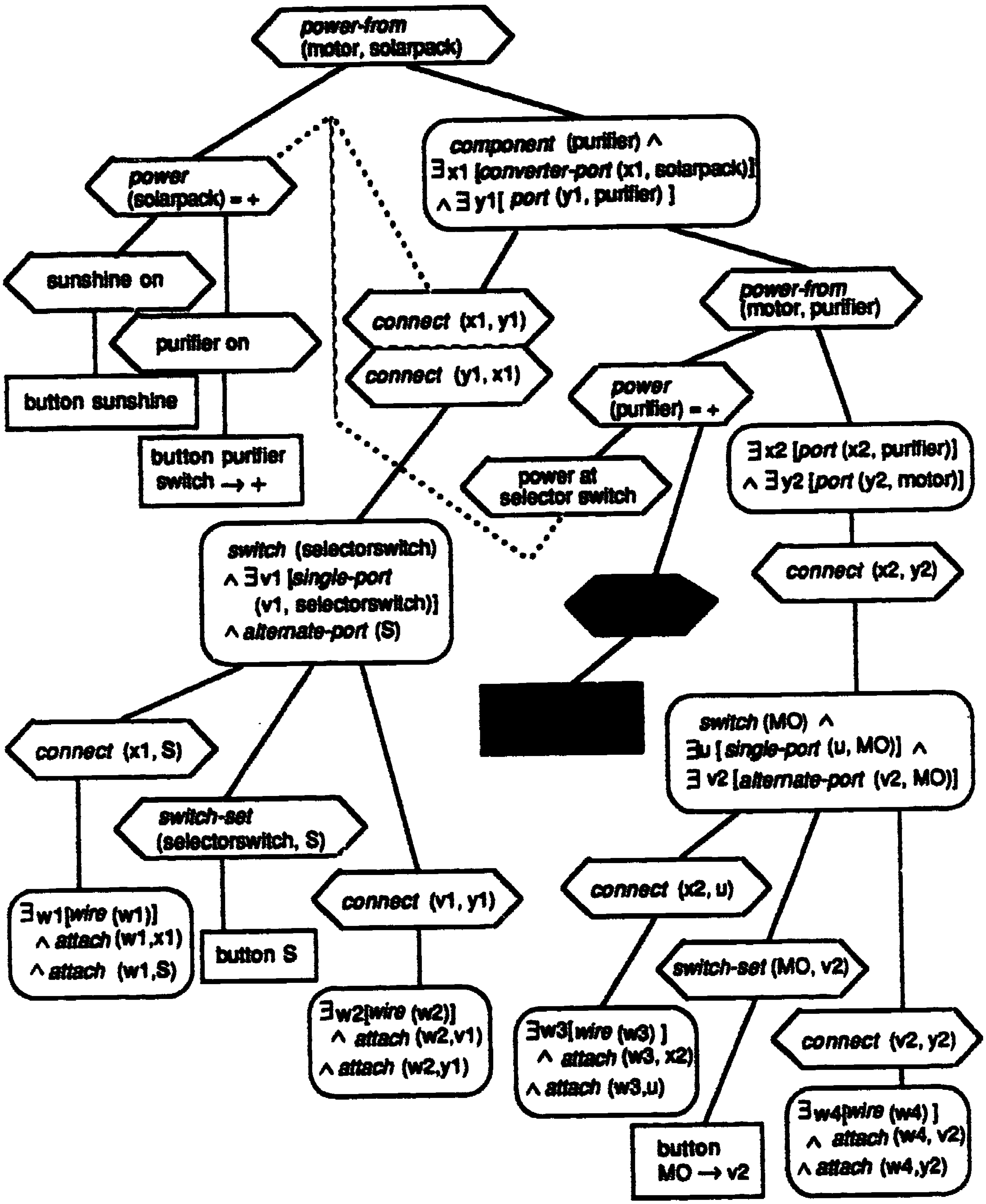
Figure 5. Schema to connect two ports.

Two ports are connected if there is a wire w that is attached to both of the ports, or if there is a switch s, with a single port u that is connected to x and an alternate port v (i.e., one of several alternatives) that is connected to y and the switch is set to v. The third alternative, *connect* (y,x), makes the property symmetrical.

A planning net for solving the first operational task is shown in Figure 6. The hexagons in Figure 6 are goals, the rounded rectangles are required conditions that are satisfied in the situation, according to the diagram, and the rectangles are actions that the participant had to perform. The planning net is generated by starting with the task goal, finding a schema that has that goal as a consequence, and including that schema's requirements as goals. Some of these goals may be satisfied in the situation; the rest must be set as goals to be achieved with further planning. (The two shaded blocks are components that are duplicated in different parts of the network.)

We have examined the instruction in the functional and component conditions, coordinating the information in the instruction with the general information in schemata and with the more specific items in the planning nets.

The information in the three schemata was not presented directly in either the functional or the component instruction. The functional instruction included information that would be relevant for inferring the first and third schemata, Figures 3 and 5. The component instruction included information that would be relevant for inferring the second schema, Figure 4.



Information in the functional instruction relevant to the schema for getting power from one component to another included: "There are three possible power sources for a VST2000 each of which is in the form of a different medium. (1) The sun's rays are one medium, and (2) the second comes in the form of the recently developed permanent power tablet. (3) The third energy agent is in the rechargeable vegetable matter of an energy bar" (screen 10F); and "A typical consumer (destination) of power in an earth vehicle is its engine. However, before reaching the VST2000's motor, the energy sources just introduced must be captured, transformed, forwarded, and then purified" (screen 12F). The instruction proceeded to discuss the functions of capturing, transforming, forwarding, and purifying, indicating which of the components were responsible for each function. We hypothesize that participants would be encouraged to infer that the transmission of power required passing through the various components in a path, as the schema of Figure 3 specifies.

The schema for getting power at a component, Figure 4, was not presented in general terms in any of our instruction. Specific versions of this were presented, however, in the component instruction. For example, concerning the tablograph, "As a whole the tablograph has two states, halt and produce, which are set with the state selector switch. When in the produce P position, there is an impulse signal with the value of 1 present at the ports of the TaO connector plug. However, no signal is present at the connector plug when the switch is in the halt H position" (screen 15S). Information in the component instruction about the solar and vegetor sources included explicit information about the necessary states of the sun and the vegetable energy bar.

Information in the functional instruction relevant to the schema about connecting components, Figure 5, involved connections between specific pairs of components, such as, "Energy from the tablograph or the vegetor is passed along to the impulse purifier by external lines. The solar pack is a part of the impulse purifier, so its energy is passed internally" (screen 17F), and "Instead of connecting cables to plugs on the system VST2000 seen on the screen, this system uses several switches for this purpose. Realize that each toggle in the middle of the screen represents an input or output plug for the purifier" (screen 21F).

Items of information in the component instruction that we judge to correspond to items in the planning net for the first task are shown in Figure 7. Items in Figure 7 that correspond to specific information in the instruction are cross-hatched; items that are subsumed by explicit general information are covered with diagonal lines.

We judge that two of the actions involving setting of switches are subsumed by the instruction: "To change a knob or switch, just move the mouse pointer to the desired region of a toggle and press the left button. If the switch does not respond, just click the left button again." (screen 3S) The action of buttoning the purifier's state switch to '+' corresponds directly to "Similar to the state switches introduced previously, the impulse purifier has a power switch that is connected to an electrical plug. When the power switch is in the '+' position and there is electricity at port 'a', electricity will flow to port 'b'. However, no electricity will flow when the switch is in the '-' position, or if there is no electricity present at port 'a'. (screen 37S) The action of buttoning the sunshine is also described specifically: "To make the sun shine, just press in the "Sunshine" button." (screen 39S)

We judge that the existence of wires attached to components corresponds to the general information, "The 'lines' on the screen represent wires that connect components. The 'lighter' colored wires on the screen carry electricity. While the 'darker' colored wires carry impulse power signals." (screen 5S)

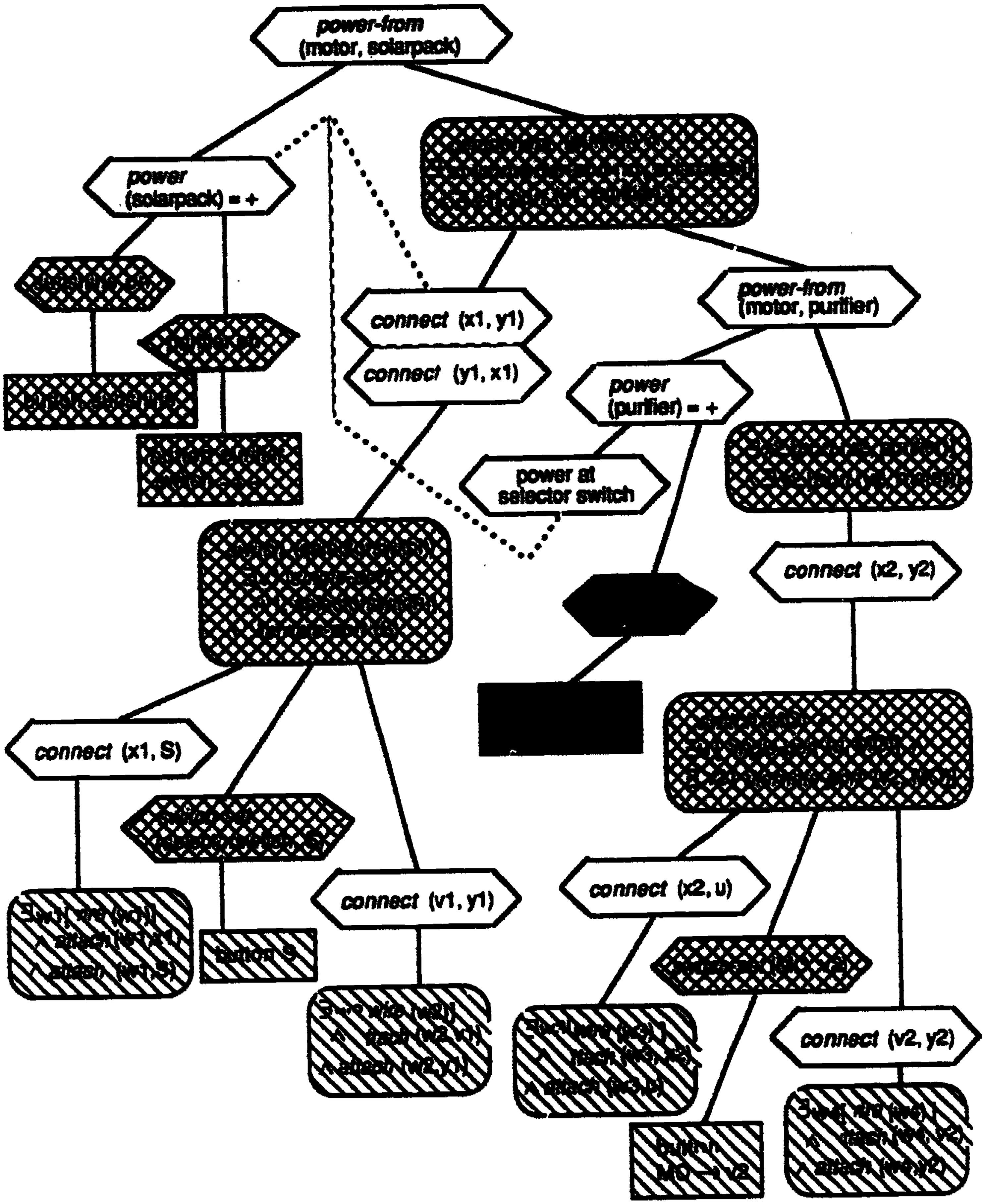


Figure 7. Planning net for Task 1 with items corresponding to information in component instruction

The cross-hatched items involving the MO switch in the planning net correspond to the instruction: "The O-type switch works in reverse. Depending upon the position of the switch, an energy signal will flow from port 'a' to either port 'b' up or ReI, or port 'c down or MoI. For example, if there is an impulse signal present at port 'a' and the switch is in the down MoI position, then the signal will flow from port 'a' to port 'c.' Like the I-type switch, no signal will flow to port 'b' or port 'c' when in the OFF position." (screen 54S) The item involving a port of the purifier and a port of the motor corresponds to information in two instructional screens: "When functioning as a complete unit the Impulse Purifier will purify the Impulse Signal selected by the Selector Switch. This laundered signal will be passed to the VO and MO connector plugs...." (screen 50S), and "Like all the other connector plugs, the MoI plug allows the VST Motor to connect to other components." (screen 57S)

We judge that the goal of having the purifier on corresponds directly to: "The next constituent part of the impulse purifier is its purifier. Like a converter, the purifier is only activated when there is electricity present at port 'c.' If so, then the purifier will launder the impulse signal present at port 'a' and pass it to port 'b.'" (screen 46S) "Realize that if there is no electricity at port 'c' or if there is no signal at port 'a,' then nothing will be purified or passed." (screen 47S)

The items involving ports of the selector switch and setting that switch to S correspond to "Another new constituent is the impulse purifier's selector switch. The switch's positions allow an impulse signal to pass from either the 'd' the S position, 'a' the T position, 'b' the V position or 'c' the A position ports to port 'e'. For example, when the selector switch is in the V position, an impulse signal will flow from port 'b' to port 'e'." (screen 43S) "However, if there is no impulse signal at port 'b' when the switch is in the V position, then no signal will be passed to port 'e'." (screen 44S)

The items involving ports of the solar pack and the purifier correspond directly to: "Like the first two components the impulse purifier has an energy converter. The converter is activated when there is electricity at port 'c'. If activated, the converter will transform raw energy that is present at port 'a' and pass it as an impulse signal with the value of 3 to port 'b'," (screen 41S) and "Another new constituent is the impulse purifier's selector switch. The switch's positions allow an impulse signal to pass from either the 'd' the S position, 'a' the T position, 'b' the V position, or 'c' the A position ports to port 's'. For example, when the selector switch is in the V position, an impulse signal will flow from port 'b' to port 'e'." (screen 43S)

Finally, the goal of making the sunshine be on corresponds to "The photo-receptor and the solar pack constituents are connected as one unit. If sunlight hits the photo-receptor, it is focused on the solar pack and is passed as raw energy to port 'a'. Realize that when the sun is not shining, no raw energy is passed." (screen 38S)

Figure 8 shows the planning net with shaded elements that we judge to correspond to items of information in the functional instruction.

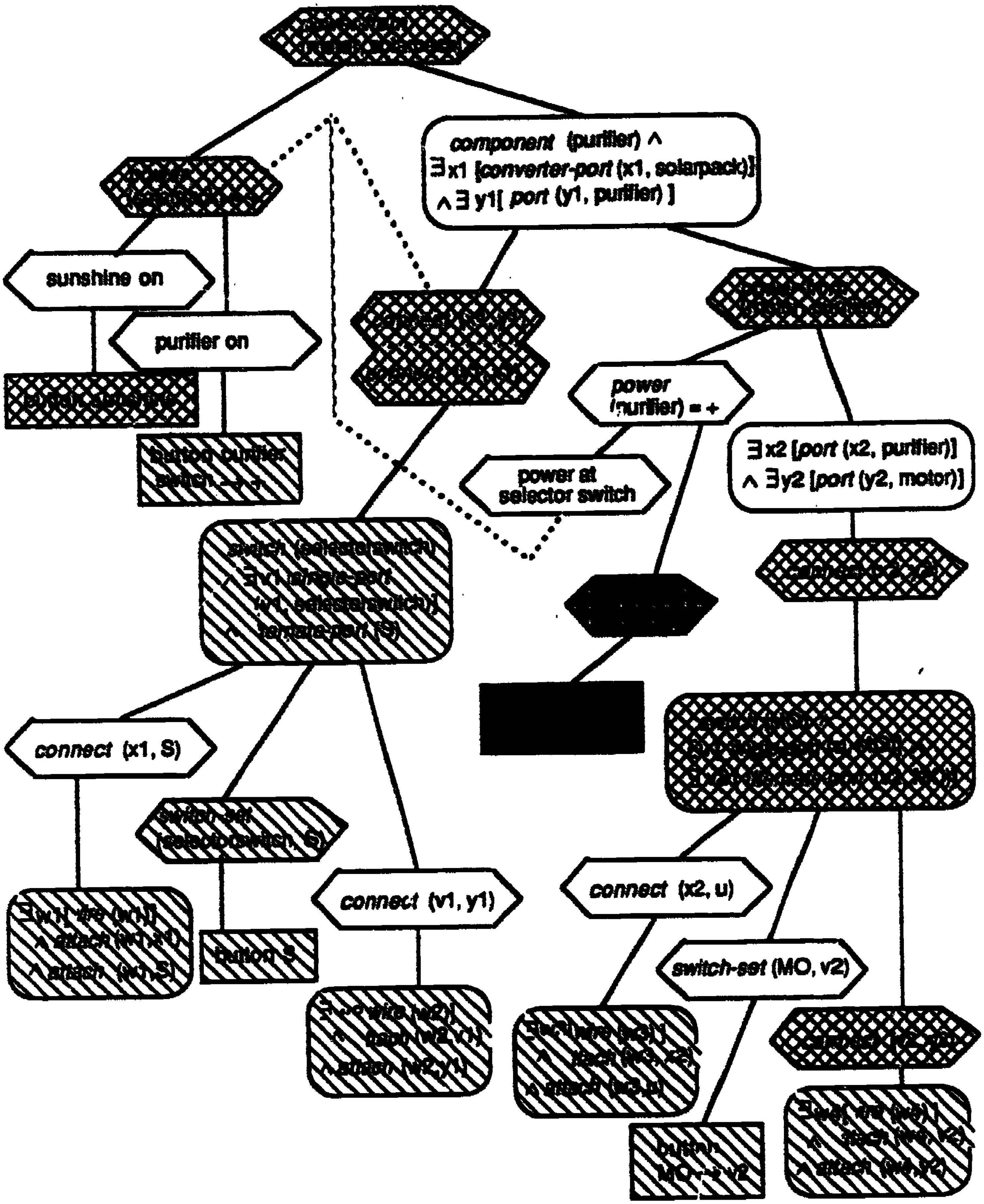


Figure 8. Planning net for Task 1 with items corresponding to information in functional instruction

We judge that one item in the instruction subsumes three of the elements of the net involving setting of switches: "To change a knob or switch, just move the mouse pointer to the desired region of a toggle and press the left button. If the switch does not respond, just click the left button again." (screen 3F = screen 3S) The "button MO" component of Figure 8 was also related to a screen about the toggle switches, "Note that the five toggles in the middle of the screen have three possible positions: (up, middle, OFF) and down. Try these switches to get used to their different positions' appearance" (screen 4F). The "button sunshine" element was specifically mentioned in the functional instruction as it was in the component instruction: "To make the sun shine, just press in the 'Sunshine' button" (screen 11F = screen 39S). There also was a screen with general information about wires, as in the component instruction, "The 'lines' on the screen represent wires that connect components. The 'lighter' colored wires on the screen carry local electricity. While the 'darker' colored wires carry impulse power" (screen 7F = screen 5S).

Information about high-level goals in Figure 8 was given explicitly in the functional instruction. The goals of getting power to the motor from the sun as a power source and getting power from the sun to the solar pack correspond to information in three screens: "There are three possible power sources for a VST2000 each of which is in the form of a different medium. 1) The sun's rays are one medium, and 2) the second comes in the form of the recently developed Permanent Power Tablet. 3) The third energy agent is in the rechargeable vegetable matter of an energy bar" (screen 10F); "A typical consumer (destination) of power in an earth vehicle is its engine. However, before reaching the VST2000's motor, the energy sources just introduced must be captured, transformed, forwarded and then purified" (screen 12F); and "Each of the three sources is 'captured' differently; for instance, 1) the sun's rays are brought into the solar pack via a photo-receptor. Similarly, 2) the tablograph's absorption needle picks up energy from the power tablets, and lastly, 3) the vegetor's scanner catalyzes the vegetable matter of the energy bar" (screen 13F)

We judge that the goal of connecting the solar pack with the purifier corresponds to an item of information in a screen about connections. "Energy from the tablograph or the vegetor is passed along to the impulse purifier by external lines. The solar pack is a part of the impulse purifier, so its energy is passed internally" (screen 17F).

Information about the selector switch relevant to the solar pack is given in general terms in the functional instruction. "When an energy source connects to the purifier via external lines, the cables are attached to the VST switches and then to the purifier's input plugs. Furthermore, there is an input selector switch on the impulse purifier which allows the user to select one of the connected impulse signals" (screen 20F), and "It is important to realize that there is a correspondence between a setting on the selector switch and an input "plug" on the purifier" (screen 23F).

The goals of getting power from the purifier to the motor and of connecting the purifier to the motor corresponds to an item of information in the functional instruction, "Whatever signal is chosen will have its power laundered by the purifier and passed via external lines to the motor where the energy is finally used. Besides the engine, there is another possible destination for the purified energy signal: it can be sent to some device to be stored" (screen 27F). The switch MO is mentioned, along with its function of connecting the purifier with a destination device: "There are three input plugs -- TI, VI and AI, where the external source components' cables (i.e., PrO and TaO) connect. The other two toggles VO and MO, are the purifier's output plugs which can connect to destination device lines -- ReI and MoI" (screen 22F).

A summary of the correspondence between the component and functional instruction and the planning net is in Table 10. The elements of the planning net are divided into nine types, in three categories. There are three types that are strictly about connections between components: power-from, connect, and wire (with attachments). There are two types that are strictly about the states of components: power state and button actions for the states of components. And there are four types that are about the ports of components and switches, which specify states of components that are involved in functional connections. The table shows the numbers of the elements that we judged to correspond to specific information in the two kinds of instruction, the numbers of elements that were subsumed by general information, and the numbers that did not correspond to information in the instruction. The functional instruction provided more information than the component instruction about the items involving connections between components, and the component instruction provided more information than the functional instruction about items involving the states of components, including states that relate to connections between components.

Table 11 shows the summary corresponding to Table 10 for the four tasks given on the initial trial: running the motor with energy from the solar pack, the tablograph, and the vegetor, and recharging the vegetor with energy from the solar pack.

These statistics reflect the differences between the component and functional instruction that we have discussed throughout this paper. The functional instruction presented more information than the component instruction about connections between components. In this experiment, the component instruction presented more information than the functional instruction about the states of components that affect connections between components -- in particular, about the states of switches. The component instruction also presented some more information than the functional instruction about the states of individual components.

We also have made an analysis of the instruction from the previous experiment (Greeno & Berger, 1987). The planning nets for the first task are shown in Figures 9 and 10.

Table 10

Frequencies of Correspondence:

Task 1 Elements and Instruction

Element Type	Num. in Task	Cmpt. Instruction			Fctnl. Instruction		
		Spec.	Subs.	None	Spec.	Subs.	None
Power-From	2	0	0	2	2	0	0
Connect	6	0	0	6	3	0	3
Wire, Attach	4	0	4	0	0	4	0
Compons., Ports	2	2	0	0	0	0	2
Switch, Ports	2	2	0	0	1	1	0
Switch-Set	2	2	0	0	0	1	1
Button Switch	2	0	2	0	0	2	0
Power State	5	2	0	3	1	0	4
Button Component	2	2	0	0	1	1	0
Total Connections	12	0	4	8	5	4	3
Total States for Connections	8	6	2	0	1	4	3
Total Single States	7	4	0	3	2	1	4

Table 11

Frequencies of Correspondence:

Initial-Trial Tasks

Element Type	Num. in Task	Cmpt. Instruction			Fctnl. Instruction		
		Spec.	Subs.	None	Spec.	Subs.	None
Power-From	8	0	0	8	8	0	0
Connect	28	0	0	28	16	0	13
Wire, Attach	18	0	18	0	0	18	0
Compons., Ports	8	8	0	0	0	0	8
Switch, Ports	10	10	0	0	6	4	0
Switch-Set	10	10	0	0	0	4	6
Button Switch	10	0	10	0	0	10	0
Power State	22	10	0	12	4	0	18
Button Component	9	9	0	0	2	7	0
Total Connections	54	0	18	36	24	18	12
Total States for Connections	38	28	10	0	6	18	14
Total Single States	31	19	0	12	6	7	18

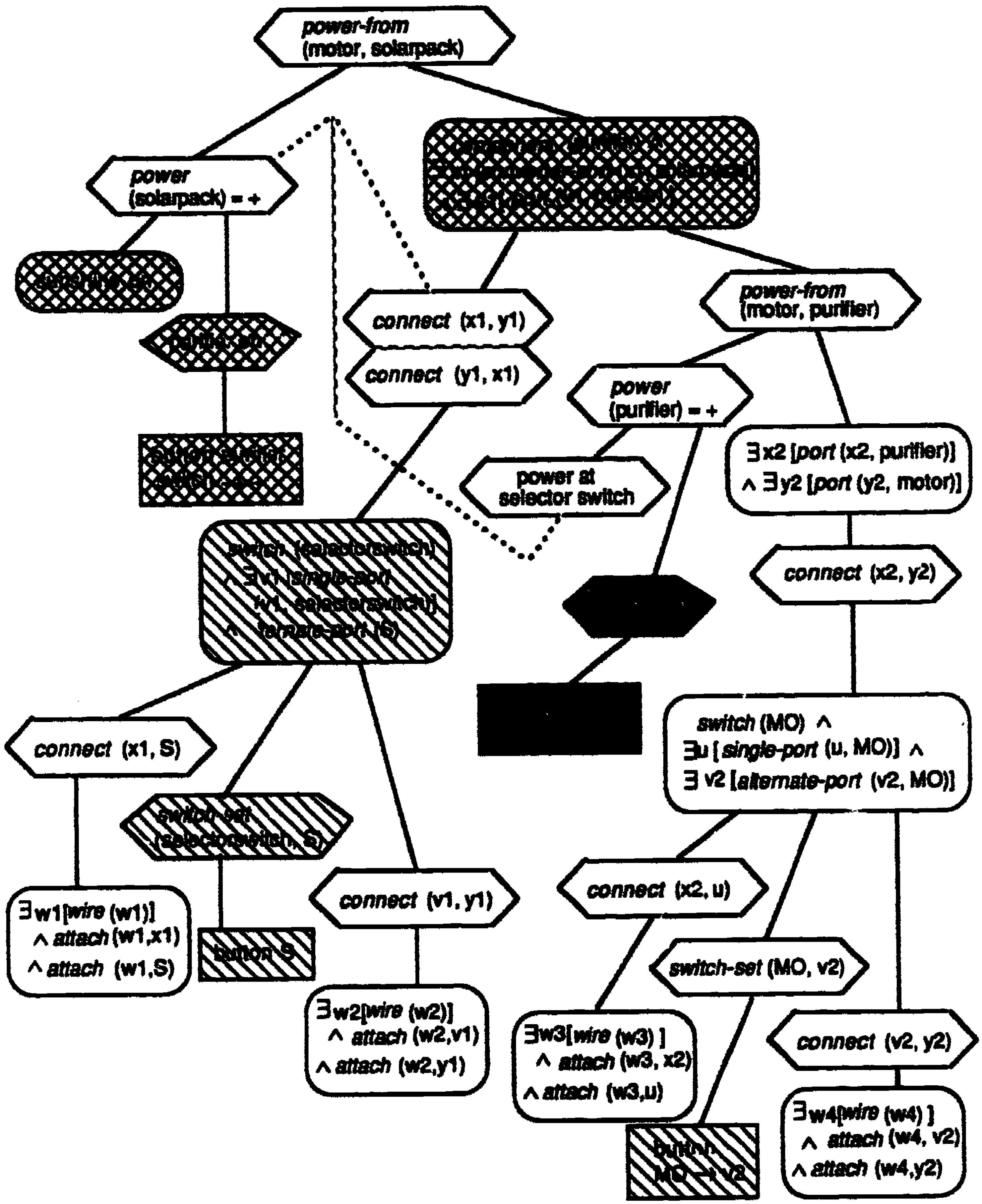


Figure 9. Planning net for Task 1 with items corresponding to information in component instruction given by Greeno and Berger (1987)

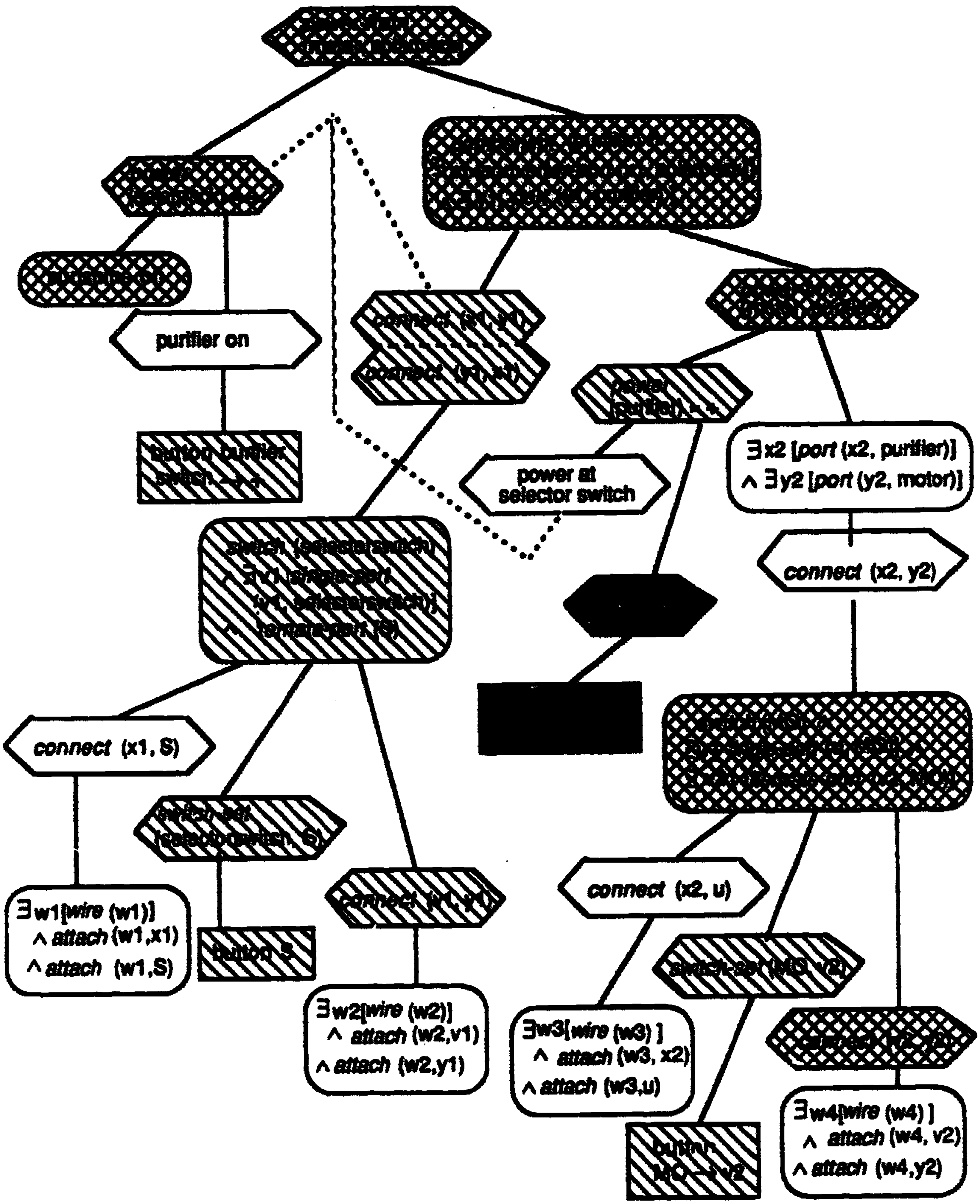


Figure 10. Planning net for Task 1 with items corresponding to information in functional instruction given by Greeno and Berger (1987)

Statistical summaries of information in the two kinds of instruction corresponding to elements of the planning nets are given in Tables 12 and 13.

Table 12

Frequencies of Correspondence: Task 1 Elements and Instruction Given by Greeno and Berger (1987)

Element Type	Num. in Task	Cmpt. Instruction			Fctnl. Instruction		
		Spec.	Subs.	None	Spec.	Subs.	None
Power-From	2	0	0	2	2	0	0
Connect	6	0	0	6	1	2	3
Wire, Attach	4	0	0	4	0	1	3
Compons., Ports	2	1	0	1	1	0	1
Switch, Ports	2	0	1	1	1	1	0
Switch-Set	2	0	1	1	0	2	0
Button Switch	2	0	2	0	0	2	0
Power State	5	2	0	3	3	1	1
Button Component	1	1	0	0	0	0	1
Total Connections	12	0	0	12	3	3	6
Total States for Connections	8	1	4	3	2	5	1
Total Single States	6	3	0	3	3	1	2

Comparison of the statistics in Tables 12 and 13 with those in Tables 10 and 11 clarifies how the instruction in the two experiments produced the different results that we obtained. In Greeno and Berger's (1987) experiment, specific information in the functional instruction corresponded to about 40% of the elements of all three of the general categories in the planning nets, while specific information in the component instruction corresponded to practically none of the elements involving connections between components or states of switches that determine connections. There was information in the component instruction specifically about the control of single components, but this was apparently not sufficient, in the absence of information about connections, to provide a basis for inferring procedures or learning. In the present experiment, with switches treated as components of the system, specific information in the functional instruction corresponded to nearly one-half of the planning-net elements involving connections between components, but there was little specific information about states of switches that determine connections. In contrast, specific information in the component instruction corresponded to about three-fourths of the planning-net elements involving states of switches. The component instruction also included specific information about more of the planning-net elements involving the states of single components than the functional instruction in both experiments, although the difference was somewhat greater in the present experiment than in Greeno and Berger's (1987) experiment.

Table 13

Frequencies of Correspondence: Initial-Trial Task Elements and Instruction Given by Greeno and Berger (1987)

Element Type	Num. in Task	Cmpt. Instruction			Fctnl. Instruction		
		Spec.	Subs.	None	Spec.	Subs.	None
Power-From	8	0	0	8	8	0	0
Connect	28	0	0	28	10	8	10
Wire, Attach	18	0	0	18	3	3	12
Compons., Ports	8	4	0	4	4	0	4
Switch, Ports	10	0	4	6	8	2	0
Switch-Set	10	0	2	8	3	7	0
Button Switch	10	0	10	0	0	10	0
Power State	22	9	0	13	11	4	7
Button Component	10	8	2	0	0	3	7
Total Connections	54	0	0	54	21	11	22
Total States for Connections	38	4	16	18	15	19	4
Total Single States	32	17	2	13	11	7	14

Descriptions of solutions of the diagnostic problems in terms of procedures are not very illuminating. The goal of an action is usually to provide information that changes the problem space; therefore, any single network like Figure 6 presents only a small fragment of the potential problem space.

The problem space for a diagnostic problem involves a set of possible faults and a series of tests that reduce the set of possibilities or attempt to determine where the fault is. As an example, the first diagnostic task had the switches set for providing power to the motor from the tablograph, but the "T" signal did not appear. This indicates that there was a fault somewhere on the path from the tablograph to the motor, or that one of the relevant components, the tablograph or the purifier, was not in the "on" state. The fault was in the TI switch. Power was passed from the tablograph to the switch at position TaO, but no power was on the TI plug on the other side of the switch.

An effective method for finding the fault would be to systematically test every constituent that might be broken. More efficient methods apply alternate procedures to test several constituents simultaneously. For the first task, one alternate procedure is to use the tablograph but route the power through a different switch from TI. This will cause the motor to run with the "T" signal and enable the inference that the faulted constituent is in the path between the TaO plug and the selector switch. Another possibility is to use the vegetor and route its power through the TI switch. The motor will not run, enabling the inference that there is a fault on the path from the TI switch to the motor.

In the empirical results, both functional and component instruction were beneficial for participants in the proportions of problems that were solved correctly and the proportions of correct explanations that were given. The effect of component instruction on explanations was greater than the effect of functional instruction. On one measure of solution efficiency -- the proportion of tasks with replacements of unflawed constituents -- both functional and component instruction had significant positive effects.

On two measures of strategic performance, however, only the functional instruction mattered. On the use of alternate operations and in the occurrence of redundant inspection tests, participants with instruction in the functional relations among components had better scores than participants without functional instruction, and the effects of component instruction were not significant.

The picture that emerges from the two experiments is consistent with Kieras's (1984) conclusions, based on a simulation model, that knowledge of the device topology is important for operating a device. The device topology has two distinguishable sets of elements: information about connections between components and information about states of components, such as switches, that determine the connectivity between components. In our previous experiment, we gave functional instruction with significant information of both kinds and component instruction with neither. The functional instruction provided a good basis for inferring and learning procedures, and the component instruction was largely ineffective, despite its inclusion of significant information about the control of the states of single components. In the present experiment, functional instruction provided significant information about connections between components, and component instruction provided significant information about states of switches. Both kinds of instruction provided significant facilitation for inferring and learning operating procedures.

Regarding diagnostic problem solving, both the component instruction and the functional instruction of the present experiment contributed to participants' success in solving problems. The component instruction was differentially more effective than functional instruction only in a minor way, involving the adequacy of explanations that they could give about correct solutions. The functional instruction, however, was differentially more effective than the component instruction regarding strategic aspects of diagnostic problem solving.

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References

Bibby, P. A., & Payne, S. J. (1989). Knowledge of devices: Internalisation of instructional descriptions? Departments of Psychology and Computing, University of Lancaster.

deKleer, J., & Brown, J. S. (1981). Mental models of physical mechanisms and their acquisition. In J. R. Anderson (Ed.), *Cognitive skills and their acquisition.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Greeno, J. G., & Berger, D. (1987). A model of functional knowledge and insight (Report No. GK-1). School of Education, University of California, Berkeley.

Kieras, D. (1984). A simulation model for procedure inference from a mental model for a simple device. Technical Report No. 15 (UARZ/DP/TR-84/ONR-15). Department of Psychology, University of Arizona.

Kieras, D. (1988). What mental model should be taught: Choosing instructional content for complex engineered systems. In J. Psotka, L. D. Massey, & S. A Mutter (Eds.), *Intelligent tutoring systems: Lessons learned* (pp. 85-112). Nillsdale, NJ: Lawrence Erlbaum Associates.

Kieras, D., & Bovair, S. (1984). The role of a mental model in learning to operate a device. *Cognitive Science*, 8, 255-273.

Towne, D. M., & Munroe, A. (1988). The intelligent maintenance system. In J. Psotka, L. D. Massey, & S. A. Mutter (Eds.), *Intelligent tutoring systems: Lessons learned* (pp. 479-528). Hillsdale, NJ: Lawrence Erlbaum Associates.

Appendix I

Interaction Instruction Screens

SCREENA

You will be taught several procedures on how to operate the device which appears on the screen. Each step in a procedure involves changing a component's switch or knob setting.

SCREENB

A task is completed when the requested letter appears in the VST Indicator, the right most component image. For example, if the task is to make the device work with V, then you have done this when a "V" appears in the VST box.

SCREENC

The help command window above the VST2000 diagram offers 3 different forms of aid: INFOrmation, RESETing the switches and displaying the current TASK.

SCREEND

To RESET the switches or to see the TASK instructions, just click the left button in the appropriate selection box. However, when you click in the INFO selection box, you will be shown a menu of topics. By selecting a menu item, you will be shown helpful information on the subject.

SCREENE

To change a knob or switch, just move the mouse pointer to the desired region of a toggle and press the left button. If the switch does not respond, just click the left button again.

SCREENF

Note that the 5 toggles in the middle of the VST2000 diagram have three possible position: up, middle (OFF) and down. Try these switches to get used to their different positions' appearances

SCREENG (This screen is not shown to the Control group)

Furthermore, you should refer to the Abbreviations Chart for explanations of SOME of the component's symbols

SCREENH (This screen is not shown to the Component or Control groups)

There are 3 input plugs - TI, VI and AI, where the external source components' cables (i.e. PrO and TaO) connect. The other two toggles, VO and MO, are the purifier's output plugs which can connect to destination device lines - ReI and MoI.

SCREENI

Remember that a task is completed when the requested letter appears in the VST box, the right most component image. For example, if the task is to make the device work with V, then you have done this when a "V" appears in the VST box.

Appendix II

Functional Instruction Screens

SCREEN1F

You are going to be taught about a fictitious device which has been simulated on the computer. During the instruction, you are expected to learn about how an energy signal originates and flows from an energy source, passes through the purifier and reaches a destination device.

SCREEN2F

(if Diagnostic.Day then) Yesterday, you were taught several operating procedures for the VST2000 system. Today, you will be asked to fix the system when it malfunctions

(else) Today, you will be taught several operating procedures for the VST2000 system. Tomorrow, you will be asked to fix the system when it malfunctions.

SCREEN3F

To change a knob or switch, just move the mouse pointer to the desired region of a toggle and press the left button. If the switch does not respond, just click the left button again.

SCREEN4F

Note that the 5 toggles in the middle of the screen have three possible positions: (up, middle OFF) and down. Try these switches to get used to their different positions' appearances

SCREEN5F

A new Earth vehicle has been developed out of the world's need for more efficient energy consuming devices. This new product, VST2000, looks very similar to standard vehicles, but is quite different in its power supply system.

SCREEN6F

The type of energy that the system generates is known as Impulse Power. However, system components use electricity to make their constituent parts work.

SCREEN7F

The "lines" on the screen represent wires that connect components. The "lighter" colored wires on the screen carry local electricity. While the "darker" colored wires carry Impulse power.

SCREEN8F

This device has two attractive features. First, it can receive power from different sources while simultaneously storing the energy. Second, an owner can easily connect the parts of the VST2000 power supply system in different arrangements.

SCREEN9F Question

One of the attractive features of the VST2000 system is

a: its similarity to other power supply systems.
b: there is just one arrangement to the system.
c: the ability to use and store energy simulatneously.

SCREEN10F

There are three possible power sources for a VST2000 each of which is in the form of a different medium. 1) The sun's rays are one medium, and 2) the second comes in the form of the recently developed Permanent Power Tablet. 3) The third energy agent is in the rechargable vegetable matter of an Energy Bar.

SCREEN11F

To make the sun shine, just press in the "Sunshine" button.

SCREEN12F

A typical consumer (destination) of power in an earth vehicle is its engine. However, before reaching the VST2000's motor, the energy sources just introduced must be captured transformed, forwarded and then purified.

SCREEN13F

Each of the three sources is "captured" differently; for instance, 1) the sun's rays are brought into the Solar Pack via a Photo-Receptor. Similarly, 2) the Tablograph's absorption needle picks up energy from the Power Tablets, and lastly, 3) the Vegetor's scanner catalyzes the vegetable matter of the Energy Bar.

SCREEN14F

Furthermore, the Energy Bar can only be scanned once for energy, after which it must be recharged.

SCREEN15F Question

Sun rays, a power tablet and rechargble vegetable matter

a: are similar mediums whose energy is captured differently.
b: are different mediums and are captured differently.
c: capture different types of energy similarly

SCREEN16F

After the energy sources are captured they need to be transformed, and each component accomplishes this with a Power Converter. This device converts the captured energy so that the energy that comes from each of the source components is in a single form: an impulse signal.

SCREEN17F

Energy from the Tablograph or the Vegetor are passed along to the Impulse Purifier by external lines. The solar pack is a part of the Impulse Purifier, so its energy is passed internally.

SCREEN18F Question

External lines are needed to pass energy to the Impulse Purifier from

a: the Solar Pack and the Vegetor.
b: the Tablograph and the Solar Pack.
c: the Vegetor and the Tablograph.

SCREEN19F Question

Signals which reach the Impulse Purifier

a: are in different forms depending on the signal's source component.
b: are always passed via external lines.
c: are in a single form.

SCREEN20F

When an energy source connects to the purifier via external lines, the cables are attached to the VST Switches and then the purifier's input plugs. Furthermore, there is an input selector switch on the Impulse Purifier which allows the user to select one of the connected impulse signals.

SCREEN21F

Instead of connecting cables to plugs on the system VST2000 seen on the screen, this system uses several switches for this purpose. Realize that each toggle in the middle of the screen represents an input or output plug for the purifier.

SCREEN22F

There are 3 input plugs - TI, VI and AI, where the external source components' cables (i.e. PrO and TaO) connect. The other two toggles, VO and MO, are the purifier's output plugs which can connect to destination device lines - ReI and MoI.

SCREEN23F

It is important to realize that there is a correspondence between a setting on the Selector Switch and an input "plug" on the purifier.

SCREEN24F

For example, if the selector switch is set to "Vegetor", and this component's external line is plugged into the vegetor input plug (i.e. VI is set to PrO), then this device's impulse signal will flow into the purifier. However, if either the vegetor's external line is not plugged in or the selector is not in the "Vegetor" position, then the Energy Bar signal will not flow.

SCREEN25F

Furthermore, since energy from all of the different mediums has been transformed into a single form (i.e. an impulse signal), any component's energy signal can be plugged into another component's input plug.

SCREEN26F Question

The tablograph signal will be forwarded when its external line is plugged into

a: the auxiliary input plug and the switch setting is "Tablograph".
b: the tablograph input plug and the switch is set to "Tablograph".
c: the tablograph input plug and the switch is set anywhere.

SCREEN27F

Whatever signal is chosen will have its power laundered by the purifier and passed via external lines to the motor where the energy is finally used. Besides the engine, there is another possible destination for the purified energy signal: it can be sent to some device to be stored.

SCREEN28F

Recall that an attractive feature of this system is that it can simultaneously use and store energy, and in a VST200 power system the storage device is the Vegetor's Energy Bar. So in addition to or instead of passing the signal to the motor, the energy can be sent from the Impulse Purifier along some external cables to the Vegetor.

SCREEN29F

When the laundered signal is sent to the Vegetor, it is first reconverted into raw power by the Vegetor's Power Converter. Then as the Scanner passes over the Energy Bar, the vegetable matter is recharged.

SCREEN30F

There are two safety features in the system which prevents the VST Motor from over loading. The first is in the Impulse Purifier's purifier: when it receives a signal greater than it can handle, the purifier automatically shuts off.

SCREEN31F

The second feature which prevents the motor from overloading involves the two output switches, MO and VO. These switches cannot both be up or down at the same time. For instance, if the VO switch is in the up position, then when you flip the MO switch up, the MO switch will automatically be set to "OFF".

SCREEN32F Question

The signal selected on the Impulse Purifier

a: can be sent to more than one device at a time.
b: cannot be stored while it is being used.
c: may be used to recharge the Tablograph.

Appendix III

Component Instruction Screens

SCREEN1S

You are going to be introduced to several components which make up the VST2000 system.

SCREEN2S

(if Diagnostic.Day then) Yesterday, you were taught several operating procedures for the VST2000 system. Today, you will be asked to fix the system when it malfunctions.

(else) Today, you will be taught several operating procedures for the VST2000 system. You are expected to learn the states of the system's components and how the components work in these states. Tomorrow, you will be asked to fix the system when it malfunctions.

SCREEN3S

To change a knob or switch, just move the mouse pointer to the desired region of a toggle and press the left button. If the switch does not respond, just click the left button again.

SCREEN4S

There are 5 different components in this system, and they are: (1) a Tablograph, (2) a Vegetor, (3) an Impulse Purifier, (4) a VST Motor and (5) several VST Switches. Furthermore, each of these system components is made up of several constituent parts, and you will be introduced to all of these.

SCREEN5S

The "lines" on the Screen represent wires that connect components. The "lighter" colored wires on the Screen carry electricity. While the "darker" colored wires carry Impulse Power Signals.

SCREEN6S

Furthermore, the value at one end of a wire will be the same as the value at the other end of the wire.

SCREEN7S

The Tablograph is a device made up of 6 constituent parts. These are: (1) a State Selector Switch, (2) an Energy Converter, (3) an Absorption Needle, (4) a Permanent Power Tablet, (5) an electrical plug and (6) the TaO connector plug.

SCREEN8S

DIAGRAM T.State.Switch

The Tablograph receives its electricity at the electrical plug, and this plug connects to the State Selector Switch. If there is electricity present at port "a", then when the switch is in the P Produce position, electricity is passed from port "a" to port "b". When in the H Halt position, the switch does not pass any electricity.

SCREEN9S QUESTION

DIAGRAM T.State.Switch

The Tablograph's Selector Switch will always pass electricity

a: when in the "P" position.
b: if there is electricity at its "a" port and it is in the "P" position.
c: if there is electicity at its "a" port.

SCREEN10S

DIAGRAM Tablet

Another part of the tablograph is the Permanent Power Tablet. This tablet is made up of an infinite number of particles that are constantly giving off benign Raw Tablet Power.

SCREEN11S

DIAGRAM Needle

The third constituent part of the Tablograph is the Absorption Needle. If there is electricity present at the Needle's port "b", it can capture raw power at its point and pass the power out at port "a". If there is no electricity present at port "b", then the needle cannot capture or pass the raw power.

SCREEN12S

DIAGRAM T-Converter

The next part of the tablograph is the Power Converter. The converter is activated when electricity is present at port "a". When activated, the converter takes Raw Tablet Power from port "b" and transforms it into an Impulse Energy Signal with the value of 1 . The Impulse Signal leaves the converter at port "c". If there is no electricity to activate the Power Converter, it will not transform or pass a signal.

SCREEN13S QUESTION

DIAGRAM T-Converter

When activated, the Tablograph's Power Converter

a: will have electricity at port "a".
b: takes raw power from port "b" and transforms and sends it as Impulse Energy to port "c".
c: does both a and b above.

SCREEN14S

DIAGRAM Tri-Plug

The Tablograph's final constituent is the TaO connector plug which allows the Tablograph to connect to other components. TaO is a Tri-Plug which allows the Tablograph to make 3 connections. Thus in the diagram above, ports "b", "c" and "d" all receive the value at port "a".

SCREEN15S

As a whole the Tablograph has two states, Halt and Produce, which are set with the State Selector Switch. When in the Produce P position, there is an Impulse Signal with the value of 1 present at the ports of the TaO connector plug. However, no signal is present at the connector plug when the switch is in the Halt H position.

SCREEN16S QUESTION

Which constituents of the Tablograph need electricity to work?

a: The Power Converter and the Absorption Needle.
b: The State Selector Switch and the Permanent Power Tablet.
c: the Power Converter and the TaO Connector Plug.

SCREEN17S QUESTION

Which statement is false?

a: The State Selector Switch determines the state of the Tablograph.
b: The Tablograph can connect to other components.
c: There is always an Impulse Signal at the TaO connector plug.

SCREEN18S

Another component in the system, the Vegetor, has 8 constituent parts, many of which are similar to the Tablograph's parts. The Vegetor's parts are: (1) a State Selector, (2) an Energy Converter, (3) a Scanner, (4) an Energy Bar, (5) the Setup Button, (6) an electrical plug and (7 and 8) two connector plugs, PrO and ReI.

SCREEN19S

DIAGRAM Veg.State.Switch

Like the Tablegraph, the Vegetor receives its electricity at its electrical plug which is connected to its State Selector Switch. If there is electricity present at port "a", then when the selector is set to "P" Produce , electricity with a value of 1 is passed to port "b". Similarly, when the selector is in the "R" Recharge position and there is electricity at port "a", electricity with a value of 2 is passed to port "b".

SCREEN20S

DIAGRAM Veg.State.Switch

When the State selector is in the H Halt position, no electricity is passed. Furthermore, if there is no electricity present at port "a", then none is passed regardless of the selector's position.

SCREEN21S QUESTION

DIAGRAM Veg.State.Switch

When electricity is present at port "a" in the Vegetor's State Selector,

a: electricity will always be present at port "b".
b: there are three posible states of the Vegetor.
c: and the selector is in the "R" position, electricity of value 1 is passed to port "b".

SCREEN22S

DIAGRAM Energy.Bar

The next constituent of the Vegetor, the Energy Bar, is the result of many years of intensive research. It is made up of vegetable matter that can be scanned for energy. This vegetable matter can only be scanned once after which it must be recharged.

SCREEN23S

DIAGRAM Scanner

Another part of the Vegetor is the Scanner. When electricity with value 1 is present at port "c", the scanner moves along the track left to right . If there is charged vegetable matter in contact with its head, then raw energy will be passed to port "b". Something slightly different happens if there is electricity with the value of 2 present at port "c". In this case, the scanner will move along the track, and its head will recharge any vegetable matter it is in contact with, if there is an energy signal at port "b".

SCREEN24S

DIAGRAM Scanner

If there is no electricity at port "c", then the scanner will stop moving across the track. Furthermore, when the scanner is at the far right end of the track, then the scanner will move back to the beginning of the track (i.e. the far left), if there is an electrical signal present at port "a".

SCREEN25S QUESTION

The Vegetor's scanner

a: automatically moves back to the beginning of the track when it reaches the far right end.
b: can scan the Energy Bar several times before recharging.
c: must be in contact with vegetable matter to pass raw energy.

SCREEN26S

DIAGRAM Scanner.Setup

One of the simplest parts of the whole VST2000 system is the Setup Button. When the button is pressed, an electrical signal is sent out port "a".

SCREEN27S

DIAGRAM V.Converter

Another one of the Vegetor's constituents that is similar to the Tablograph's is the Energy Converter. Like the Tablograph's converter the Vegetor's converter is activated when electricity is present at port "d". When activated with an electrical value of 1, the converter takes raw energy from port "a", transforms it into an Impulse Energy Signal with the value of 2 and passes the signal to port "c".

SCREEN28S

DIAGRAM V.Converter

The reverse happens when the converter is activated by electricity with the value of 2 . In this instance, if an Impulse Energy Signal is present at port "b", then the converter transforms the signal into raw energy and passes it to port "a".

SCREEN29S

Like many other constituents, if there is no electricity to activate the Power Converter, then no energy will be transformed or passed.

SCREEN30S QUESTION

DIAGRAM V.Converter

When the Vegetor's converter is activated with an electrical value of 1,

a: it transforms an Impulse Signal into raw energy.
b: raw energy is taken from port "a", transformed into an Impulse signal and passed to port "c".
c: the scanner moves from right to left.

SCREEN31S

The Vegetor's last two constituents, the PrO and ReI plugs, allow the Vegetor to connect with other system components. Like the Tablograph's TaO plug, the PrO plug is a Tri-Plug, so it can make three connections. The ReI plug, however, can only make one connection.

SCREEN32S

When the Vegetor's constituents are put together, the device has three states that can be selected with the State Selector. When in the Produce P state, the Vegetor's scanner passes over the Energy Bar, and if the bar is charged, then there will be an Impulse Energy Signal with the value of 2 present at the PrO connector plug.

SCREEN33S

The reverse happens when the Vegetor is in the Recharge R state: if an Impulse Energy Signal is present at the ReI connector plug, then the Scanner will charge the bar. When in its final, Halt H state, the Vegetor will neither recharge the bar nor produce an energy signal.

SCREEN34S

Remember that the Energy Bar can only be scanned once for energy, after which it must be recharged.

SCREEN35S QUESTION

When the Vegetor is in the "P" state,

a: the Energy Bar will get charged.
b: an Energy Signal may be present at the PrO plug.
c: the scanner moves from right to left.

SCREEN36S

The next component in the VST2000, the Impulse Purifier, has some parts similar to the previous two components and some that are quite different. It has 12 constituent parts, which are: (1 and 2) a Photo-Receptor/Solar Pack unit, (3) an Energy Converter, (4) a Selector Switch, (5) a Purifier, (6) a Power Switch, (7) an electrical plug and (8-12) 5 connector plugs, TI, VI, AI, VO and MO.

SCREEN37S

DIAGRAM P.Power.Switch

Similar to the state switches introduced previously, the Impulse Purifier has a Power Switch that is connected to an electrical plug. When the Power Switch is in the "+" on position and there is electricity at port "a", electricity will flow to port "b". However, no electricity will flow when the switch is in the "-" off position, or if there is no electricity present at port "a".

SCREEN38S

DIAGRAM SolarPack

The Photo-Recepter and the Solar Pack constituents are connected as one unit. If sunlight hits the Photo-Recepter, it is focused on the Solar Pack and is passed as raw energy to port "a". Realize that when the sun is not shining, no raw energy is passed.

SCREEN39S

To make the sun shine, just press in the "Sunshine" button.

SCREEN40S QUESTION

The Solar Pack

a: passes raw energy only when the sun is shining.
b: directly receives sunlight and passes it as raw energy.
c: stores sunlight received from the Photo-Receptor.

SCREEN41S

DIAGRAM SP.Converter

Like the first two components the Impulse Purifier has an Energy Converter. The converter is activated when there is electricity at port "c". If activated, the converter will transform raw energy that is present at port "a" and pass it as an Impulse Signal with the value of 3 to port "b".

SCREEN42S

DIAGRAM SP.Converter

If there is no raw energy at port "a" or if there is no electricity present at port "c", then the converter will not transform or pass any energy.

SCREEN43S

DIAGRAM P.Selector.Switch

Another new constituent is the Impulse Purifier's Selector Switch. The switch's positions allow an Impulse Signal to pass from either the "d" the S position, "a" the T position, "b" the V position or "c" the A position ports to port "e". For example, when the Selector Switch is in the V position , an Impulse Signal will flow from port "b" to port "e".

SCREEN44S

DIAGRAM P.Selector.Switch

However, if there is no Impulse Signal at port "b" when the switch is in the V position, then no signal will be passed to port "e".

SCREEN45S QUESTION

DIAGRAM P.Selector.Switch

When the Impulse Purifier Selector Switch is in the "T" posiiton

a: an Impulse Signal will always flow from port "a" to port "e".
b: an Impulse Signal will be present at port "a".
c: a signal will flow to port "e" provided an Impulse Signal is present at port "a".

SCREEN46S

DIAGRAM Purifier

The next constituent part of the Impulse Purifier is its Purifier. Like a converter, the purifier is only activated when there is electricity present at port "c". If so, then the purifier will launder the Impulse Signal present at port "a" and pass it to port "b".

SCREEN47S

DIAGRAM Purifier

Realize that if there is no electricity at port "c" or if there is no signal at port "a", then nothing will be purified or passed.

SCREEN48SA

DIAGRAM Purifier

There is a safety feature in the Impulse Purifier's purifier which prevents the system from over loading. When the purifier receives a signal with a value greater than 3 at port "a", it automatically shuts off and does not send a signal out port "b".

SCREEN49S

DIAGRAM PLUG

Like the connector plugs on the previous components, the TI, VI, AI, VO and MO plugs allow the Impulse Purifier to connect to the other components in the system.

SCREEN50S

When functioning as a complete unit the Impulse Purifer will purify the Impulse Signal selected by the Selector Switch. This laundered signal will be passed to the VO and MO connector plugs. If the Photo-Receptor is receiving sunlight, the Impulse Purifier's Solar Pack will generate an Impulse Energy Signal with the value of 3 .

SCREEN51S QUESTION

When the Impulse Purifier is functioning as a complete unit

a: the laundered signal will be present at only one of the VO or MO connector plugs.
b: the Impulse Signal to be laundered is determined by the Selector Switch.
c: the Solar Pack can always generate a signal which can be selected by the Selector Switch.

SCREEN52S

DIAGRAM TI.Switch

There are two different types of VST Switches in the system. The first is an I-Type switch of which there are three: TI, VI and AI. There are two of the other, O-Type, switches: VO and MO. For I-Type switches, if there is an energy signal at port "b" and the switch is in the up TsO position, then the signal will flow from port "b" to port "a". Likewise, when in the down PrO position, an energy signal will flow from port "c" to port "a" if there is an Impulse Signal present at port "c".

SCREEN53S

DIAGRAM TI.Switch

When in the OFF position, no signal will flow to port "c".

SCREEN54S

DIAGRAM MO.Switch

The O-Type Switch works in reverse. Depending upon the position of the switch, an energy signal will flow from port "a" to either port "b" up or ReI or port "c" down or MoI . For example, if there is an Impulse Signal present at port "a" and the switch is in the down MoI position, then the signal will flow from port "a" to port "c". Like the I-Type switch, no signal will flow to port "b" or port "c" when in the OFF position.

SCREEN55S QUESTION

I-type switches

a: have two Impulse Energy "source" ports.
b: have two Impulse Energy "destination" ports.
c: have one Impulse Energy "source" port.

SCREEN56S

The last component in the VST2000 system is the VST Motor. It is made up of 2 constituent parts, 1 the VST Indicator and 2 the MoI connector plug.

SCREEN57S

Like all the other connector plugs, the MoI plug allows the VST Motor to connect to other components.

SCREEN58S

DIAGRAM Indicator

The last constituent to be examined is the VST Indicator. Depending upon the value of the signal present at port "a", a different letter will appear in the indicator. For example, if the signal has a value of 3, then an "S" will apear in the indicator. Other values are: 0 or no signal - nothing in the indicator; 1 - a "T" in the indicator; and 2 - a "V" in the indicator.

SCREEN59S QUESTION

The Indicator

a: always shows the same letter.
b: reflects the signal present at the MoI plug.
c: reflects the state of the Impulse Purifier.

Appendix IV

Component and Functional Instruction Screens

SCREEN1B

You are going to be taught about the VST2000 Power Supply System which has been simulated on the computer. During the instruction, you are expected to learn the states of the system's components and how the components work in these states. You will also learn about how an energy signal originates and flows from an energy source, passes through the purifier and reaches a destination device.

SCREEN2B

(if Diagnostic.Day then) Yesterday, you were taught several operating procedures for the VST2000 system. Today, you will be asked to fix the system when it malfunctions.

(else) Today, you will be taught several operating procedures for the VST2000 system. Tomorrow, you will be asked to fix the system when it malfunctions.

SCREEN3B

To change a knob or switch, just move the mouse pointer to the desired region of a toggle and press the left button. If the switch does not respond, just click the left button again.

SCREEN4B

A new Earth vehicle has been developed out of the world's need for more efficient energy consuming devices. This new product, VST2000, looks very similar to standard vehicles, but is quite different in its power supply system.

SCREEN5B

This device has two attractive features. First, it can receive power from different sources while simultaneously storing the energy. Second, an owner can easily connect the parts of the VST2000 power supply system in different arrangements.

SCREEN6B QUESTION

One of the attractive features of the VST2000 system is

a: its similarity to other power supply systems.
b: there is just one arrangement to the system.
c: the ability to use and store energy simultaneously

SCREEN7B

There are 5 different components in this system, and they are: (1) a Tablograph, (2) a Vegetor, (3) an Impulse Purifier, (4) a VST Motor and (5) several VST Switches.

Furthermore, each of these system components is made up of several constituent parts, and you will be introduced to all of these.

SCREEN8B

The type of energy that the system generates is known as Impulse Power. However, system components use electricity to make their constituent parts work.

SCREEN9B

The "lines" on the screen represent wires that connect components. The value at one end of a wire will be the same as the value at the other end of the wire.

SCREEN10B

Furthermore, the "lighter" colored wires on the screen carry local electricity. While the "darker" colored wires carry Impulse power.

SCREEN11B

DIAGRAM: PLUG

Connector plugs are used in this system to connect wires from one component to another component. Similar to wires, the value at the "b" port of a plug will be the same as the value at the "a" port.

SCREEN12B

DIAGRAM: Tri-Plug

A similar type plug has 3 connection ports. The value of port "a" is passed to all of the connection ports. Thus in the diagram above, ports "b", "c" and "d" all receive the value at port "a".

SCREEN13B QUESTION

The VST2000 system

a: generates electrical power and uses Impulse power to make constituent parts work.
b: generates Impulse power and uses electricity to make constituent parts work.
c: has connector plugs that alter the values passed between the plug's ports.

SCREEN14B

Three of the 5 different components in the VST2000 system are source components: the Impulse Purifier's Photo-Receptor/Solar Pack unit, the Tablograph and the Vegetor. Each of these source components gets its energy from a different medium.

SCREEN15B

The Photo-Receptor/Solar Pack unit gets energy from the sun's rays; the Tablograph gets its energy from a Permanent Power Tablet; and the Vegetor's energy comes from the rechargable vegetable particles of an Energy Bar.

SCREEN16B

DIAGRAM: Tablet

The Tablograph receives its raw energy from a Permanent Power Tablet. This tablet is made up of an infinite number of particles that are constantly giving off benign Raw Tablet Power.

SCREEN17B

DIAGRAM: Energy.Bar

The Vegetor gets its raw energy from an Energy Bar. It is made up of vegetable matter that can be scanned for energy. This vegetable matter can only be scanned once after which it must be recharged.

SCREEN18B

To make the sun shine on the Photo-Receptor, just press in the "Sunshine" button.

SCREEN19B QUESTION

The Tablograph, the Vegetor and the Solar Pack

a: are the 3 destination components of the system.
b: get their raw energy from a Power Tablet, an Energy Bar and the sun's rays, respectively.
c: get their raw energy from similar mediums.

SCREEN20B QUESTION

The Vegetor's Energy Bar

a: can only be scanned once after which it must be recharged.
b: is made up of an infinite number of particles that are constantly giving off raw energy.
c: can be scanned many times before being recharged.

SCREEN21B

The three source components have several similar constituents. First, each has a State Switch or Power Switch, which receives electricity from an electrical plug. Depending upon the position of the switch, this received electricity may or may not be passed by the switch.

SCREEN22B

The Tablograph's State Switch has 2 positions, "H" and "P" which correspond to the Halt and Produce states.

SCREEN23B

DIAGRAM: T.State.Switch

The Tablograph receives its electricity at the electrical plug, and this plug connects to the State Selector Switch. If there is electricity present at port "a", then when the switch is in the "P" Produce position, electricity is passed from port "a" to port "b". When in the "H" Halt position, the switch does not pass any electricity.

SCREEN24B QUESTION

The Tablograph's State Switch will always pass electricity

a: when in the "P" position.
b: whenever it receives electricity from the electrical plug.
c: if it receives electricity from the electrical plug and it is in the "P" position.

SCREEN25B

Similarly, the Impulse Purifier has a Power Switch with 2 positions: "+" on and "-" off .

SCREEN26B

DIAGRAM: P.Power.Switch

The Impulse Purifier has a Power Switch that is connected to an electrical plug. When the Power Switch is in the "+" on position and there is electricity at port "a", electricity will flow to port "b". However, no electricity will flow when the switch is in the "-" off position, or if there is no electricity present at port "a".

SCREEN27B

The Vegetor has a State Switch, much like the Tablograph's, but the Vegetor's has an additional position, "R", which corresponds to the Recharge state.

SCREEN28B

DIAGRAM: Veg.State.Switch

Like the Tablograph, the Vegetor receives its electricity at its electrical plug which is connected to the State Selector. If there is electricity present at port "a", then when the selector is set to "P" Produce , electricity with a value of 1 is passed to port "b".

SCREEN29B

DIAGRAM: Veg.State.Switch

Similarly, when the selector is in the "R" Recharge position and there is electricity at port "a", electricity with a value of 2 is passed to port "b". Furthermore, when the Selector Switch is in the "H" Halt position, no electricity will be passed.

SCREEN30B QUESTION

The Vegetor's State Switch

a: is similar to the Tablograph's State Switch but the Vegetor's has an additional "R" position.
b: has only 2 possible states.
c: can pass electricity with a value of 1, 2 or 3 .

SCREEN31B

As previously mentioned, each source component gets its raw energy from a different medium. Once again, these sources are the sun's rays, the Permanent Power Tablet and the Energy Bar. Each source component has a constituent for capturing the raw energy.

SCREEN32B

There are 3 "capturing" constituents in the system. (1) The Impulse Purifier's Photo-Receptor brings the sun's rays to the Solar Pack. (2) The Tablograph's Absorption Needle picks up energy from the Power Tablets. And (3) the Vegetor's Scanner catalyzes the vegetable matter of the Energy Bar.

SCREEN33B

DIAGRAM: Needle

Raw Tablet Power is captured by the Tablograph's Absorption Needle. If the Needle receives electricity frcm the Tablograph's State Switch at port "b", it can capture raw power at its point and pass the power out at port "a". If there is no electricity present at port "b", then the needle cannot capture or pass the raw power.

SCREEN34B QUESTION

The Absorption Needle

a: captures raw energy from vegetable matter.
b: is the Impulse Purifier's capturing constituent.
c: captures raw power at its point when activated by electricity from its State Switch.

SCREEN35B

DIAGRAM: Scanner

Similarly, the charged particles of the Vegetor's Energy Bar are captured by the Scanner. When the Vegetor is in the Produce P state, the Scanner receives electricity with value 1 from the Vegetor's State Switch at port "c". In this state, the Scanner moves along the track left to right . If the Energy Bar is charged, then raw energy will be passed to port "b".

SCREEN36B

DIAGRAM: Scanner

When the Vegetor is in the Recharge R state something slightly different happens. The Scanner is activated by the Vegetor's State Switch with electricity of value 2 at port "c". In this case, the Scanner will move along the track, and its head will recharge the Energy Bar's vegetable matter via port "d" if there is an energy signal at port "b".

SCREEN37B

DIAGRAM: Scanner

If the Scanner receives no electricity from the State Switch at port "c", then the Scanner will stop moving across the track. Furthermore, when the Scanner is at the far right end of the track, then the Scanner will move back to the beginning of the track (i.e. the far left), if there is an electrical signal present at port "a".

SCREEN38B

DIAGRAM: Scanner.Setup

The Scanner receives its setup signal from one of the simplest parts of the whole VST2000 system, the Setup Button. When this button is pressed, an electrical signal is sent out its port "a".

SCREEN39B

DIAGRAM: SolarPack

The third "capturing" constituent in the VST2000 system is the Photo-Recepter/Solar Pack unit. If sunlight hits the Photo-Recepter, it is focused on the Solar Pack and is passed as raw energy to port "a". Realize that when the sun is not shining, no raw energy is passed.

SCREEN40B QUESTION

DIAGRAM: Scanner

The Vegetor's Scanner

a: will recharge the Energy Bar if there is an energy signal at port "b" and the Vegetor is in the Recharge R state.
b: will always pass raw energy when in the Produce P state.
c: is activated by the Setup Button.

SCREEN41B QUESTION

The Solar Pack

a: stores sunlight received from the Photo-Receptor.
b: directly receives sunlight and passes it as raw energy.
c: passes raw energy only when the sun is shining.

SCREEN42B

After the energy sources are captured they need to be transformed, and each component accomplishes this with a Power Converter. This device converts the captured raw energy so that the energy that comes from each of the source components is in a single form: an Impulse Signal.

SCREEN43B

Futhermore, each converter creates an Impulse Signal. with a different value. The Tablograph's converter creates a signal with value 1; the Impulse Purifier's converter, a value 3; and the Vegetor's converter creates an impluse signal with the value 2 .

SCREEN44B QUESTION

Each source component's converter

a: transforms electricity into an Impulse Signal.
b: creates an Impulse Signal with a different value.
c: captures and transforms raw energy from different mediums.

SCREEN45B

DIAGRAM: T-Converter

The Tablograph's Power Converter is activated by electricity from its State Switch at port "a".

SCREEN46B

DIAGRAM: T-Converter

When activated, the Converter takes the Raw Tablet Power it received from the Absorption Needle at port "b" and transforms it into an Impulse Energy Signal with the value of 1 . This Impulse Signal is passed to the Tablograph's TaO connector plug via port "c". If there is no electricity to activate the Power Converter, it will not transform or pass a signal.

SCREEN47B

When the constituents of the Tablograph are put together, the device has two states, Halt and Produce, which are set with the State Selector Switch.

SCREEN48B

When in the Produce P state, the Absorption Needle, which has been activated by the Selector Switch, captures benign energy from the Permanent Power Tablet. The Converter, which has been activated similarly, transforms the raw energy, which is then passed to the TaO connector plug as an Impulse Signal with the value of 1 . However, no signal is present at the TaO connector plug when the Tablograph is in the Halt H state.

SCREEN49B

DIAGRAM: V.Converter

Like the Tablograph's Converter, the Vegetor's Converter is activated when electricity is received from its State Switch at port "d".

SCREEN50B

DIAGRAM: V.Converter

When activated with an electrical value of 1 the Vegetor is in the Produce state , the Converter takes the raw energy it received from the Scanner at port "a" and transforms it into an Impulse Energy Signal with the value of 2 . This Impulse Signal is passed to the Vegetor's PrO connector plug from port "c".

SCREEN51B

DIAGRAM: V.Converter

The reverse happens when the Vegetor is in the Recharge R state; the Converter is activated by electricity with the value of 2 at port "d". In this instance, if an Impulse Energy Signal is received from the Vegetor's ReI connector plug at port "b", then the Converter transforms the signal into raw energy and passes it to the Vegetor's Scanner from port "a".

SCREEN52B

If there is no electricity from the State Switch to activate the Power Converter, then no energy will be transformed or passed.

SCREEN53B

When the Vegetor's constituents are put together, the device has three states that can be selected with the State Selector Switch.

SCREEN54BA

When in the Produce P state, the Vegetor's Scanner, which has been activated by the Selector Switch, passes over the Energy Bar and captures the raw energy if the Bar is charged . The Converter, which is also activated by the Selector Switch, transforms the raw energy, which is then passed to the PrO connector plug as an Impulse Signal with the value of 2 .

SCREEN55B

The reverse happens when the Vegetor is in the Recharge R state: if the Converter receives an Impulse Energy Signal from the ReI connector plug, it will transform the Impulse Energy into raw energy and pass it to the Scanner, which then charges the Energy Bar. As in the Produce state, the Converter and the Scanner are activated by the Selector Switch.

SCREEN56B

When in its final, Halt H state, the Vegetor will neither recharge the bar nor produce an energy signal.

SCREEN57B QUESTION

The Vegetor is different from the Tablograph because

a: the Vegetor passes an Impulse Signal to its connector plug.
b: the Vegetor can recharge its source of raw energy (i.e. the Energy Bar).
c: the Vegetor's capturing constituent and Converter are activated by the State Switch.

SCREEN58B

DIAGRAM: SP.Converter

Like the first two components the Impulse Purifier has an Energy Converter. The Converter is activated when it receives electricity from its Power Switch at port "c". If activated, the Converter will take raw energy received from the Solar Pack at port "a" and transform it into an Impulse Signal with the value of 3 . The Impulse Signal then leaves the Converter at port "b".

SCREEN59B

DIAGRAM: SP.Converter

If the Converter does not receive electricity from the Power Switch at port "c", then the Converter will not transform or pass any energy.

SCREEN60B

Energy from the Tablograph and the Vegetor are passed to the Impulse Purifier along external lines. The Solar Pack is a part of the Impulse Purifier, so its energy is passed internally.

SCREEN61B QUESTION

External lines are needed to pass energy to the Impulse Purifier from

a: the Solar Pack and the Vegetor.
b: the Tablograph and the Solar Pack.
c: the Vegetor and the Tablograph.

SCREEN62B

The Tablograph and the Vegetor connect to the external lines via output plugs. The Tablograph has a TaO Tablograph Out connector plug while the Vegetor has a PrO Produce Out connector plug.

SCREEN63B

When the Tablograph or the Vegetor connect to the Purifier via external lines, the cables are attached to the Purifier's input plugs. The Purifier has 3 input plugs - TI Tablograph In , VI Vegetor In and AI Auxiliary In .

SCREEN64B

For each input plug there is a switch that determines which signal goes to that plug. Thus, the system has TI, VI and AI switches that correspond to the TI, VI and AI input plugs.

SCREEN65B

DIAGRAM: TI.Switch

The TI, VI and AI switches are all the same kind of switch, an I-Type switch. If the switch receives an Impulse Signal from the Tablograph at port "b" and the switch is in the up TaO position, then the signal will flow from port "b" to port "a". Likewise, when in the down position PrO , an energy signal will flow from port "c" to port "a" if an Impulse Signal is received from the Vegetor at port "c".

SCREEN66B

DIAGRAM: TI.Switch

Furthermore, when the switch is in the OFF position, no signal will flow to port "a".

SCREEN67B QUESTION

The TI, VI and AI switches

a: correspond to the Purifier's output plugs.
b: can receive a signal from either the Tablograph or the Vegetor.
c: will pass a signal when set at any position.

SCREEN68B

The Selector Switch on the Impulse Purifier determines which input plug's signal to purify. The Selector Switch has 4 positions: "S" for Solar Pack, "T" for Tablograph, "V" for Vegetor and "A" for Auxiliary.

SCREEN69B

DIAGRAM: P.Selector.Switch

The Selector Switch's positions allow an Impulse Signal to pass from either the "d" the "S" position , "a" the "T" position , "b" the "V" position or "c" the "A" position ports to port "e". For example, when the Selector Switch is in the V position , an Impulse Signal will flow from port "b" to port "e".

SCREEN70B

DIAGRAM: P.Selector.Switch

However, if there is no Impulse Signal at port "b" when the switch is in the "V" position, then no signal will be passed to port "e".

SCREEN71B

Because the Solar Pack is connected internally to the Impulse Purifier, when the Selector Switch is in the "S" position, it always selects the signal from the Solar Pack.

SCREEN72B

DIAGRAM: P.Selector.Switch

The other 3 positions - "T", "V" and "A" - correspond to the input plugs, TI, VI and AI. Setting the Selector Switch to one of these positions determines which input plug's signal should be purified.

SCREEN73B

DIAGRAM: P.Selector.Switch

It is important to realize that the Tablograph or the Vegetor can be connected to any of the 3 input plugs TI, VI or AI . Thus, there is a correspondence between a setting on the switch and an input "plug": setting the Selector Switch to either the "T", "V" or "A" position only determines which input plug's signal to purify. It does not determine a particular source component except in the case of the "S" setting.

SCREEN74B QUESTION

The Tablograph signal will be forwarded when its external line is plugged into

a: the auxiliary input plug and the switch setting is "Tablograph".
b: the Tablograph input plug and the switch is set to "Tablograph".
c: the Tablograph input plug and the switch is set anywhere.

SCREEN75B

Once the Impulse Signal is received by the Impulse Purifier it must be laundered by the purifier, which is another constituent of the Impulse Purifier.

SCREEN76B

DIAGRAM: Purifier

Like a converter, the purifier is only activated when it receives electricity from its Power Switch at port "c". When activated, the purifier will launder the Impulse Signal received from the Selector Switch at port "a" and pass it to the VO and MO connector plugs via port "b".

SCREEN77B

When functioning as a complete unit the Impulse Purifer will purify the Impulse Signal selected by the Selector Switch. This laundered signal will be passed to the VO and MO connector plugs. If the Photo-Receptor is receiving sunli t, the Impulse Purifier's Solar Pack will generate an Impulse Energy Sign ith the value of 3 .

SCREEN78B QUESTION

When the Impulse Purifier is functioning as a complete unit

a: the laundered signal will be present at only one of the VO or MO connector plugs.
b: the Impulse Signal to be laundered is determined by the Selector Switch.
c: the Solar Pack can always generate a signal which can be selected by the Selector Switch.

SCREEN79B

The laundered signal is passed from the Impulse Purifier through external lines. These output lines connect to the Impulse Purifier via the Purifier's output plugs, VO Vegetor Out and MO Motor Out.

SCREEN80B

Similar to the Impulse Purifier's input plugs, the output plugs have corresponding switches. These switches, MO and VO, are both O-Type switches, which determine the destination of the laundered energy signal.

SCREEN81B

DIAGRAM: MO.Switch

The O-Type switches work in reverse when compared to I-Type switches. Depending upon the position of the switch, an energy signal will flow from port "a" to either port "b" up or ReI position or port "c" down or MoI .

SCREEN82BA

DIAGRAM: MO.Switch

For example, if the switch receives an Impulse Signal and the switch is in the down MoI position, then the signal will flow from port "a" to port "c". Like the I-Type switch, no signal will flow to port "b" or port "c" when the switch is in the OFF position.

SCREEN83B

There are two possible destinations for the laundered Impulse Energy: 1 the VST Motor and 2 the Vegetor. Recall that an attractive feature of this system is that it can simultaneously use and store energy. The storage device in this system is the Vegetor's Energy Bar. So in addition to or instead of passing the signal to the motor, the energy can be sent from the Impulse Purifer along some external cables to the Vegetor.

SCREEN84B

The VST motor receives its energy from the Impulse Purifier via external lines that connect to the motor's MoI Motor In connector plug. While the Motor is not visible on the screen, its Indicator is.

SCREEN85B

DIAGRAM: Indicator

The VST Indicator shows the kind of signal being received by the Motor. Depending upon the value of the signal present at port "a", a different letter will appear in the Indicator For example, if the signal has a value of 3, then an "S" will apear in the Indicator Other values are: 0 or no signal - nothing in the Indicator 1 - a "T" in the Indicator and 2 - a "V" in the Indicator

SCREEN86B

DIAGRAM: Purifier

There are two safety features in the system which prevents the VST Motor from over loading. The first is in the Impulse Purifier's purifier: when it receives a signal with a value greater than 3 at port "a", the purifier automatically shuts off.

SCREEN87B

The second feature which prevents the motor from overloading involves the two output switches, MO and VO. These switches cannot both be up or down at the same time. For instance, if the VO switch is in the up position, then when you flip the MO switch up, the MO switch will automatically be set to "OFF".

SCREEN88B

The VST system can also store the purified signal by sending it to the Vegetor. The Vegetor receives this signal at its ReI plug. If the Vegetor is in the Recharge state (i.e. the State Selector Switch is set to R), the Impulse Signal received at the ReI plug will be passed to the Converter.

SCREEN89B

The now activated Converter transforms the Impulse Signal into raw energy and passes it to the Scanner. Finally, the Scanner, which has also been activated by the Vegetor's State Selector Switch, passes over and recharges the Energy Bar's vegetable matter.

SCREEN90B QUESTION

The indicator

a: confirms the signal being stored.
b: shows the signal reaching the engine.
c: reflects the state of the Impulse Purifier.

Appendix V

Day-1 Task Instructions

TASK1

TASK1: First toggle the MO switch to the MoI position. Click in the Sunshine button. Next flip the Impulse Purifier's switch to "+", and then turn the purifier's Selector Switch to "S". There should now be an "S" in the VST Indicator

TASK2

TASK2: First toggle the MO switch to the MoI position, and the TI switch to TaO. Next flip the Impulse Purifier's switch to "+", and then turn the Selector Switch to "T". Put the Tablograph's switch to "P". There should now be a "T" in the VST Indicator.

TASK3

TASK3: First toggle the MO switch to the MoI position, and the VI switch to PrO. Next flip the Impulse Purifier's switch to "+", and then turn the Selector Switch to "V". Click in the Vegetor's "P" box. The Scanner should start moving, and there should now be a "V" in the VST Indicator.

TASK4

TASK4: First toggle the MO switch to the MoI position, the VO to ReI and the VI switch to PrO. Then click in the Sunshine button. Next flip the Impulse Purifier's switch to "+", and then turn the Selector Switch to "S". There should now be an "S" in the indicator. Next click in the Vegetor's "R" box (the Scanner should start moving). After the Scanner gets to the far right, click in the Vegetor's "P" box, press its "S" button, and then turn the Impulse Purifier's Selector Switch to "V".

Appendix VI

Augmented Instruction: Malfunctions of Components

SCREEN1M

Now you are going to be introduced to the various malfunctions that have been known to effect the VST2000 system. Unfortunately, almost every part of the system is susceptible to problems.

SCREEN2M

The simplest malfunctions occur when a wire breaks. As you can imagine, when this happens the value at one end of the wire is NOT passed to the other end of the wire.

SCREEN3M

The 3 state switches all fail in similar ways. Sometimes when these switches receive electricity and are in a state that usually passes electricity (e.g. "+" and "P"), no electricity is passed.

SCREEN4M

DIAGRAM P.Power.Switch

For example, if the Impulse Purifier's Power Switch is receiving electricity at port "a" and the switch is in the "+" position, then no electricity will be present at port "b" when the switch is broken in this manner.

SCREEN5M

DIAGRAM Veg.State.Switch

While the Vegetor's State Switch can fail like just explained, it may also break in a different manner. When the switch is in the "R", Recharge, position, there may be an electrical signal with the value of 1 instead of 2 at port "b".

SCREEN6M

Another set of failures effect the Power Converters. When these failures occur, the converters do not pass any Impulse Power even though they are activated.

SCREEN7M

DIAGRAM TI.Switch

The I-Type VST Switches have been known to fail also. When these switches malfunction, the signal from both the "b" and "c" ports flow to port "a". This causes the values of the ports to be "added" and sent out port "a".

SCREEN8M

DIAGRAM TLSwitch

For example, when the switch is "up", and if there is a signal with value 1 at port "b" and another with a value of 2 at port "c", then there would be a 3 at port "a".

SCREEN9M

A similar problem sometimes happens to the Impulse Purifier's Selector Switch. When the switch is in a given position, the signals from the other positions usually do not flow. However, sometimes after over use, the other signals do flow.

SCREEN10M

DIAGRAM P.Selector.Switch

For example, the signal from port "a" may always flow. So when the switch is in the "V" position, the signal from both port "b" and "a" are sent to port "e". The signal at port "e" will then be the sum of the values of the signals from these input ports.

SCREEN11M

There are also some problems that happen to specific parts. The Solar Pack's Photo-Receptor may get dirty and the Solar Pack will be unable to produce a signal. Furthermore, the Energy Bar's vegetable matter can wear out and then is not able to be recharged.

Appendix VII

Diagnostic Instruction Screens

SCREEN1D

Yesterday you learned several operating procedures for the VST2000 system. Today when you are asked to perform tasks, the system is not going to work correctly. You are going to try to figure out which part of the VST2000 system is malfunctioning.

SCREEN2D

There are two things that will help you figure out what is wrong with the system.

SCREEN3D

The first aid in figuring out the system's problem is by using the Part Inspector. This is done by pressing the mouse's RIGHT button and moving it into or near one of the system's parts, and then releasing the button.

SCREEN4D

The Part Inspector "window" which appears contains 4 things: the name of the object;a list of the object's ports and the values at those ports; the object's diagram; and a "REPLACE" button.

SCREEN5D

Only one object will malfunction at a time. So when you think that you have found the broken part, you can replace it by clicking in the "REPLACE" button. You will then have to demonstrate that the system has been fixed.

SCREEN6D

It is very costly to replace an object, and so you should have a good reason for replacing a part. Therefore, before you press the REPLACE button you must explain why you want to replace the object. Also, you should state what you think will happen after the replacement is complete.

SCREEN7D

The second aid in helping you figure out the malfunction is that you will be shown the procedure one that you learned yesterday) that is not working correctly. You should set the switches for this task. However, it may be helpful to try other settings and procedures to locate the malfunction.

Appendix VIII

Diagnostic Task Descriptions

Task 1

Part: Tablograph State Switch
Malfunction: NO.FLOW
Type: Switch
Day 1 Procedure: S - (Task 1)

Optimal Solution:

By applying Alt Let 2 (V w/TI) the MP can quickly be reduced to include just the constituent parts of the Tablograph. For whatever part of the Tablograph is chosen with Inspect Part, there will be 0's present at all input ports. S can thus follow the malfunction back to the TSS which (when in the "P" position) will have a 1 at its input port and a 0 at its output port.

Frequent Problems:

- (All) If Alt Let 2 is not applied, then the MP will not be reduced as completely as stated above.
- (C and S groups) S may not have enough functional knowledge to apply the Alternate Operators and will have to start by using the Part Inspector.
- (All) This is the first task, and subjects have not seen the Part Inspector before and may have a little trouble getting used to it
- (C and F groups) Subjects without the component information have never seen individual parts, ports or port values before, and it is likely that they will have trouble understanding the "numbers" they see in the inspector.
- (C and F groups) As an extention and because of the previous problem, the same subjects may have a hard time interpreting what to do (i.e. how to adjust the MP) with the information shown the Inspector.

Task 2

Part: Solar Pack
Malfunction: NO.CAPTURE
Type: Functional
Day 1 Procedure: S - (Task 1)

Optimal Solution:

By applying Alt Let I (V or T) it becomes apparent (because the alternate letter will appear) that the problem must be somewhere in the Solar Pack part of the Impulse Purifier. The MP can then be reduced to include just the Solar Pack by correctly interpreting the Inspect Part operator (following the 0 inputs back to the SP).

Frequent Problems:

- (C and S groups) S may not have enough functional knowledge to apply the Alternate Operators and will have to start by using the Part Inspector.
- (C and F groups) Subjects without the component information may have a hard time interpreting what to do (i.e. how to adjust the MP) with the information shown the Inspector.

Task 3

Part: VI-PrO
Malfunction: BROKEN
Type: Wire
Day 1 Procedure: V - (Task 3)

Optimal Solution:

The **Alt Path** operator (V w/TI or AI) will immediately reduce the MP to incude just the VI switch and its connecting wires. One or two **Inspect Parts** will show that the VI-PrO wire is malfunctioning.

Frequent Problems:

- (All) If **Alt Path** is not applied, then the MP will include the Vegetor, and most subjects have a hard time understanding this component. Thus, subjects do not apply or use the Inspector correctly in the Vegetor.
- (C and S groups) S may not have enough functional knowledge to apply the Alternate Operators and will have to start by using the Part Inspector.
- (C and F groups) Subjects without the component information may have a hard time interpreting what to do (i.e. how to adjust the MP) with the information shown the Inspector.

Task 4

Part: Energy Bar
Malfunction: NO.CHARGE
Type: Functional
Day 1 Procedure: S & V - (Task 4)

Optimal Solution:

The first part of this procedure where an "S" appears will remove the Impulse Purifier from the MP. The **Alt Path** operator (V w/TI or AI) will then show that the problem is located in the Vegetor. By realizing that the problem could have occurred during the "recharge" part of the procedure, the next step is to trace the "recharge signal" through the Vegetor with several **Inspect Parts**. (Realize that the **Alt Path** operator is really not that necessary because of the location of the malfunction.) This will show that the signal is reaching the Energy Bar but not recharging it.

Frequent Problems:

- (All) The Vegetor is not well understood by most subjects, and tracing signals through this component often intimidates subjects.
- (All) If the subject does not realize that the problem could have occurred during the "recharge" phase, then it will at least take him/her a while to become aware of this possibility. However, some subjects may never realize this.
- (C group) It is likely that a subject in this group does not understand the "purpose" of this procedure (i.e. that the Solar Pack is being used to recharge the Vegetor). Thus, the subject may not notice a problem even if s/he sees the "empty" Energy Bar.
- (C and F groups) Subjects without the component information may have a hard time interpreting what to do (i.e. how to adjust the MP) with the information shown the Inspector especially since the MP includes the Vegetor.

Task 5

Part: Needle-Converter
Malfunction: Broken
Type: Wire
Day 1 Procedure: T - (Task 2)

Optimal Solution:

Similar to Task 1 above, by applying **Alt Let 2** (V w/TI) the MP can quickly be reduced to include just the constituent parts of the Tablograph. By using the **Inspect Part** operator, all the parts in the Tablograph will be seen to be functioning properly except the Converter, which will have an incorrect value at one of its input ports, and the Needle-Converter wire which will be shown to be malfunctioning.

Frequent Problems:

• (All) If **Alt Let 2** is not applied, then the MP will not be reduced as completely as stated above.
• (C and S groups) S may not have enough functional knowledge to apply the Alternate Operators and will have to start by using the Part Inspector.
• (C and F groups) These subjects may have a hard time interpreting what to do (i.e. how to adjust the MP) with the information shown the Inspector - a common error is to believe that the Tablogrph Converter is broken.

Task 6

Part: VI Switch
Malfunction: TaO.FLOWS.AT.PrO
Type: Switch
Day 1 Procedure: T - (Task 2), then V - (Task 3)

Comment on Malfunction: Subjects are told to do the T procedure (which they just did in task 5) and then do the V procedure which will work with some strange results.

The malfunction causes the T (value 1) and V (value 2) signals to be combined (to create a signal with value 3 - the same as the Solar Pack's signal's value) in the VI switch. Thus, when the SS is set to "V" and both the Tablograph and the Vegetor are on, an S appears in the indicator. Also if the switches are are set in this manner except that the Vegetor is off, then a T will appear in the indicator even though the VI switch is set to "PrO".

Optimal Solution:

After seeing the S and, when the Vegetor has stopped, the T, both of which are unexpected, the **Alt Path** operator (V w/TI or AI) will narrow the MP to include just the VI switch and its connecting wires. An **Inspect Part** of the VI switch will show a malfunction to be present in this part.

Frequent Problems:

• (All) Seeing the S causes subjects to make various inaccurate assumptions, and they then proceed with their diagnostic procedures incorrectly. Among these invalid assumptions are: believing that the Solar Pack is the source of the signal; assuming that the Vegetor, which gets recharged by the Solar Pack, is then producing a "wrong-valued signal"; thinking that the "3" that is present at one of the VI Switch's ports is "entering" the switch and not "leaving" it.
• (All) If **Alt Path** is not applied or the Vegetor is not removed from the MP because of some incorrect deduction, then the subject may get stuck working his/her way through this "difficult" component.

• (C and F groups) The subjects in these groups do not know what the values mean and may not realize the malfunction when the see it with the Inspector. Or they may say that the VI Switch looks wrong but will not be able to relate it to the "visual" problem (i.e. they do not know that a 3 causes an S to appear in the indicator).
• (C and S groups) S may not have enough functional knowledge to apply the Alternate Operators and will have to start by using the Part Inspector.
• (C and F groups) Subjects without the component information may have a hard time interpreting what to do (i.e. how to adjust the MP) with the information shown the Inspector.

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